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REGIONAL WOOD ENERGY DEVELOPMENT PROGRAMME IN ASIA
GCP/RAS/154/NET

# Proceedings

# OF THE INTERNATIONAL WORKSHOP ON BIOMASS BRIQUETTING

NEW DELHI, INDIA (3-6 APRIL 1995)

Edited by

P. D. Grover & S. K. Mishra

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**
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# FOREWORD

The International Workshop on Biomass Briquetting at the Indian Institute of Technology-Delhi, April 1995, attracted more than a hundred participants from India and other countries. This large number is not surprising considering the importance of the subject for several countries in Asia and the interesting research results obtained by the research team of IIT-Delhi and its partners which were to be presented at the workshop.

For a long time, the Indian Ministry of Non-Conventional Energy Sources and the Indian Renewable Energy Development Agency Ltd. have taken a strong interest in briquetting of biomass residues for fuel. This is true also of several other departments, institutes and organizations in Asia. RWEDP has noticed an increasing, or sometimes renewed, interest in fuel briquettes amongst both government and private sector organisations in many of its member countries in South and South-East Asia. Briquettes provide a relevant option for fuel substitution, but the option should not be advocated indiscriminately. The viability of this option depends on site- specific conditions like local resource bases, environmental conditions, fuel markets and infrastructure. Related to these, the technology adopted and scale of any briquette production system are important factors. In fact, briquetting is a process providing relatively low added value by means of relatively high technology and it is obvious that great care needs to be taken in order to secure commercial success. In the past, quite a number of naive approaches leading to disappointments for promoters, designers and entrepreneurs have been observed. In recent years, the combined ingenuity of chemists, engineers and industrial designers and the considerable business acumen of entrepreneurs have been applied to the technical, managerial and commercial challenges confronting the briquetting industry. With the knowledge and experience currently available, it should be possible to avoid further disappointments and make good use of the viable briquetting potentials which are present in many member countries. It can be observed that in some RWEDP-member countries vast quantities of wood residues are still being wasted, and cause a significant environmental hazard. With present technologies these residues could be processed into valuable fuels on a commercial scale.

The Biomass Densification Research Project, the main results of which were presented at the International Workshop, is an example of successful technical cooperation between countries in Asia and The Netherlands. The project was jointly implemented by two universities and two private sector companies: IIT- Delhi, University of Twente, Solar Sciences Consultancy Pvt. Ltd, and DENSI- TECH. It is expected that the publication of the Proceedings, with conclusions and recommendations, will stimulate and guide further, appropriate applications of briquetting technology in Asia and beyond.

A complement to the present Proceedings is the Field Document (No. 46) on 'Biomass Briquetting: Technology and Practices' by P.D. Grover and S.K. Mishra, also published by RWEDP in 1996. That document describes in more detail the potential agri- residues, briquetting fundamentals, technologies, effects of pre-heating, an example of a physical and economic analysis, and various other considerations for the production of briquettes.

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# 1. INTRODUCTION

An International Workshop on Biomass Briquetting Technologies was organised during April 3-6, 1995 by the Biomass Group of the Chemical Engineering Department of IIT, Delhi, under the sponsorship of the University of Twente, The Netherlands, and the co-sponsorship of the Indian Renewable Energy Development Agency. The workshop was attended by 25 participants from overseas and 76 from India. It was inaugurated by Mr. B.R. Prabhakara, Secretary, Ministry of Non-conventional Energy Sources, Government of India and presided over by Prof. V.S. Raju, Director, Indian Institute of Technology, Delhi. This Workshop was an opportunity to discuss the outcome of the Project on Biomass Densification Research funded by the Dutch Government's Directorate General for International Cooperation and contracted to the University of Twente, The Netherlands in 1989.

The workshop was addressed by participants from various international agencies, namely FAO, ESCAP, UNIDO; international institutes such as the Asian Institute of Technology, Bangkok and the University of Twente; IIT Delhi; Tata Energy Research Institute; officials from the Royal Embassy of the Netherlands in India and national organisations such as the Ministry of Non-conventional Energy Sources and IREDA; and by participants from the Regional Wood Energy Programme (RWEDP) in Bangkok; and participants from Nepal, Malaysia, Philippines, Vietnam, Myanmar, Indonesia, Sri Lanka and The Netherlands. The conference was addressed by the initiators and major promoters of the project, Dr. W.S. Hulscher, Dr. Joy Clancy, Prof. P.D. Grover and Mr. Hajo Brandt.

The outcome of the project "Biomass Densification" was presented by the two Co-ordinators, Prof. P.D. Grover of IIT, Delhi and Dr. Joy Clancy of the University of Twente. Dr. W.S. Hulscher, the earlier co-ordinator of the Project at the University of Twente also gave his impressions in the Keynote Address.

The report indicated that the Phase I of the project focussed on state-of-the art studies in six different countries, viz. Thailand, India, Nepal, Sri Lanka, Malaysia and the Philippines. Phase I evaluated potentials and constraints for adequate production and dissemination of biomass briquettes. The outcome observed a mismatch between technology, raw material supply and prospective markets; and certain major technical barriers, high cost of operation, and the fact that the briquettes did not necessarily contribute to the intended rural market. Thus, Phase II of the project was initiated with the following two objectives:

- To provide manufacturers with an improved technology to turn agricultural and forest residues into a suitable fuel for industrial and institutional use, also for export; and
- To verify assumptions made on socio-economic issues during Phase I of the project.

The Indian Institute of Technology, Delhi, was assigned the task of improving the technology and the Tata Energy Research Institute, Delhi, was contracted to study the socio-economic issues including environmental impact analysis. Under the technical aspects, the project focussed on two major areas of work for optimising the technologies, which are:

- To reduce the wear of the forming screw due to high friction; and
- To reduce power consumption during production.

The Shimada screw extruder briquetting machine was procured from Europe in February 1993 and regular tests have been conducted by IIT, Delhi at an industrial site of the Solar Sciences Consultancy Pvt. Ltd. in Faridabad.

The following parameters were thoroughly studied:

- Effect of particle size and shape of the agro residues for densification. The ideal size was identified to be 6-8 mm;
- Effect of moisture. Ideal level was 8 to 10 per cent;
- Effect of feed preheating studied and the temperature upto 90 to 110 degree centigrade for the feed was optimised;
- Effect of temperature on the die was found important and the temperature at 280 to 290 $^{0}$C was observed to be most appropriate and;
- Effect of mixing rice husk with bagasse and bagasse pith to achieve the briquetting of these materials.

Technology development was directed towards two approaches: selecting a suitable hardfacing alloy for depositing on screw surface, and preheating of feed biomass before its introduction to the screw press. Technological development on the machine helped in improving the life of the most critical part - the screw - from 2 hours of operation to 44 hours of operation giving 17 tonnes of briquettes before it was removed for repairs. In terms of costs, the maintenance cost of the screw dropped from Rs. 583 to Rs. 150 by using Tungstun carbide alloy for hardfacing and finally to Rs. 30 per tonne by incorporating feed preheating. In addition, the feed preheating resulted in reduction of power consumption by 30% and production rate went up by as much as 50% for some agricultural residues.

Tests were spread over 760 hours during two years of operation and different feed materials like saw dust, groundnut shells, mustard stalks, coffee husks and rice husk were extensively tested and trial runs were also made on coir pith, bagasse, bagasse pith and tea waste. Power consumption was observed to be 50 to 75 kWh per tonne of production and the cost of conversion into briquettes was observed to be Rs 500/- per tonne. The payback period for the project was projected as 2.5 years and the recommended sale price for the product was observed to be about Rs 1450/- per tonne. At the time of writing Phase II of the project is expected to be concluded in May 1995.

## 1.1. Observations of Participants

Enthused by the impressive outcome of Phase II, the participants expressed their desire that the project be extended to Phase III so as to facilitate undertaking large scale demonstrations under field conditions and subsequent development and commercialisation of technologies through entrepreneurial investments. This phase will be aimed at conducting field studies in South and South East Asia and these are to be conducted in a similar fashion as earlier field studies but with the substantial involvement of the industry and agencies already promoting commercialisation of biomass technologies. Thus, it was suggested that Phase III of the project could be taken up by the present team of Prof. P.D. Grover, Coordinator at IIT Delhi, Dr. Joy Clancy, Co-ordinator at Twente University, The Netherlands and Dr. Hajo Brandt of Densitech BV; with the assistance of the Solar Sciences Consultancy Pvt. Ltd and MAV Industries, Karur as representative industries; and with Tata Energy Research Institute and the Indian Association for the Advancement of Sciences studying the marketability and industrial acceptability of briquettes and the social and environmental aspects of briquetting technologies. This opportunity was also used to discuss the overall development in the briquetting sector and various participants gave their observations on briquetting in the region. A number of briquette manufacturers from India, Myanmar and Malaysia using machines of varying capacities from 100 to 500 kg per hour related their experiences.

The participants were extremely enthusiastic about the outcome and suggested that the experiences gained as a result of the project due to the involvement of experts in the biomass sector and various industries being a major asset. It was felt that appropriate steps must be taken to share these experiences and evolve a methodology for technology transfer through a cost effective networking arrangement. Participants from South East Asia also outlined the potentials of biomass briquetting in their respective countries and showed a keen desire to have the benefits of these developments.

## 1.2. Conclusions

Major conclusions from the workshop are as follows:

- Agro residues are an important source of biomass fuel to meet the energy needs of developing countries in the South and South East Asia region. The Indo-Dutch Project on Densification of Biomass has indicated the viability of screw press briquetting technology for locally available biomass residues. Various observations on the effect of (i) particle size of feed, (ii) preheating temperatures of feed, (iii) moisture level of feed, (iv) mixing of different residues, etc. have indicated that these are all residue specific and site specific. Agro residue characterisation and trial run of different kinds of biomass feed stock have established screw press briquetting as a technological breakthrough. Also, enhancing the screw life by appropriately managing different operational parameters establishes cost effective manufacturing of briquettes.

- The pilot scale breakthrough has laid a strong foundation for the follow up of large scale demonstration cum commercialisation of screw press briquetting technology. Subsequent promotion by financial institutions to fund briquetting projects shall be part of the project activity.

- Various international agencies such as FAO, UNDP, ESCAP, UNIDO and their assisted projects such as the Regional Wood Energy Project in this region have developed capabilities of different kinds like financing, technology transfer, manpower training etc. which can be pooled together through an appropriate information exchange mechanism. The sharing of knowledge and experience with private and public sector units in countries of the region can be promoted.

- Technology transfer through TCDC and ECDC mechanisms can be crucial and effective in the development of low cost biofuels by utilisation of agro residues in countries of the region.

- ! The needs of large industrial houses attaining economy by large scale operations demand individual briquetting machines of capacities upto 10 to 15 tonnes per day, whereas, on the other hand, the social needs in small decentralised rural areas demand briquetting machines capable of operation at about 1 tonne per day. The gamut of machines already evolved over the range 100 kg per hour to l.5 tonnes per hour have been commercially developed in India and are being effectively utilised at certain sites. However, a mechanism for their uniform utilisation under all conditions is necessary.

- ! Large scale use of briquetting machines in India and a few other South East Asian countries has created trained manpower who have evolved their own methodologies and appropriate feed mixes to attain optimum results of production.

- ! Employment generation in rural areas of developing countries of South and South East Asia is crucial in social and economic development, as was also mentioned at the Final Declaration of the Social Summit. Recent initiatives like the UNIDO Thematic Programme on Biomass Energy for Industrial Development in Africa appreciated at the workshop, need to be suitably adapted for the South and South East Asian Region.

## 1.3. Recommendations

The following recommendations have been suggested by the workshop participants:

- ! The experience gained under the Indo-Dutch Biomass Densification Research Project in India is relevant for several countries in South and South East Asia. A network of various UN and International Funding Agencies and other major project groups involved in biomass briquetting in South and South East Asia, along with various countries in this region should be set up. This network shall aim to transfer knowledge and experience to the private and public sector units to promote commercialisation of briquetting technologies through appropriate government policies in the region. A core secretariat for the network is desirable to facilitate its effective operation. To have a cost effective working arrangement for the network, the facilities at RWEDP may be utilised; and FAO be requested to provide funding through TCDC arrangement with countries of South and South East Asia. UNIDO may be requested to provide financial and in kind assistance for dissemination.

- ! Phase II of the Dutch Funded Project has established technical capabilities of the screw press briquetting technology on a pilot scale (500 kg/hr) for different kinds of biomass residue material available in India; and has also developed indicative financial projections. Now, there is a need to establish Phase III of the Project aimed at large scale commercialisation oriented demonstrations under field conditions in selected countries, in South and South East Asia, utilizing locally available agro residues to establish commercial viability. Linkages between Phase III of the Dutch Project and similar project proposals of other agencies should be established.

- ESCAP is serving most of the countries in the South and South East Asian region. It is most appropriate to request them to set-up a Sub-Group on Biomass Briquetting to promote regional cooperation. Technical assistance required for formation of the Sub Group and subsequent activities can be provided by the participants to this Workshop. The Donor Funding for the Sub Group should be organised by ESCAP. The activities of the Sub Group should be complementary to the activities of the proposed network.

- UNIDO may be requested to adapt their Thematic Programme on Biomass Energy for Industrial Development for South and South East Asia region with a focus on briquetting.

- Briquettes being a substitute for wood, their progressive use should form an integral part of National/International reforestation and environmental programmes. Financial incentives should be provided by various governments in the region to briquette manufacturers for meeting the cost incurred by them for development of a market for the sale of briquettes for at least an initial period of three years.

# 2. INAUGURAL SESSION

## 2.1. Address by Dr. W.S. Hulscher, CTA, RWEDP, Bangkok

### Genesis and Relevance of Biomass Briquetting Project

The briquetting of biomass residues first came to my mind a long time ago. It was at a workshop of the United Nations Environment Programme(UNEP) on Rural Energy Planning, in Bangkok in 1982. On that occasion, a representative of VITA, which is an NGO active in appropriate technologies, reported on his efforts to develop densification of biomass residues for fuel in Thailand, together with a Thai company. VITA reported on the technical problems which were experienced in briquetting of rice husk by high density extrusion technology. The main problems, you will not be surprised to hear, were: wear of the screw and excessive power consumption by the machine.

It was understood that I represented a Technical University, the University of Twente, and I was asked if my university could look into the matter in our laboratories, and so the Mechanical Engineering Faculty in cooperation with the Technology and Development Group of Twente University carried out some studies and in the process developed an interest in studying briquetting technology. As I said, this was in the early eighties. It soon turned out that the technical problems were far more complicated than expected and needed more than just some simple trouble shooting.

Around the same time, in 1983, I attended the World Energy Congress, which was held in Delhi. The programme included visits to energy exhibits and demonstrations, and amongst them were various interesting technologies put up at IIT, Delhi. Already by then IIT, Delhi was hosting a lively United Nations University Training Center in renewable energy technologies, with lots of foreign students. I was particularly interested in small hydro systems, but I happened to come across various demonstrations at the Department of Chemical Engineering on pyrolysis and gasification, as well as the PARU technology for densification of carbonised biomass, then newly developed by Prof. Grover. It was the first time I had met with Prof. Grover and my interest in briquetting deepened, as I was most impressed by the ingenuity of the technical designs.

In the following years a number of activities were undertaken by Twente University to study the briquetting of rice husk in Thailand, from where the orignal research definition came, as well as in The Netherlands. One of our problems in The Netherlands was that the country did not grow any rice, so rice husk for testing had to be imported all the way from Italy. A policy of Twente University was, and still is, to involve its post-graduate students in research assignments. Several Masters' degree students in technical and management studies were involved, including Mr. Hajo Brandt, now Director of DENSI-TECH. The students did field studies in Thailand and consulted private sector industries, government departments, NGOs and, for instance, Kasetsart University in Bangkok. The Agricultural Engineering Department at that university was very active in low pressure briquetting of residues. Dr. Wattana of Kesetsart had developed what he called a `green fuel machine'.

In the meantime, we had learned that briquetting of residues for fuels was a relevant option for several countries in South and South-East Asia, and our enthusiasm for the research increased further. In the late eighties we considered that it was time to seek funding for intensified research cooperation with Kasetsart University and other institutes in the region. With strong inputs from our new graduate, Mr. Hajo Brandt, a proposal was prepared for submission to the Dutch Government for funding of further research and development. From then on, it took some time, but finally, a preparatory phase was approved; this was phase I of the `Biomass Densification Research Project'.

The project encompassed 6 countries in Asia, namely Thailand, The Philippines, Malyasia, India, Nepal and Sri Lanka. The focus of this first phase was not yet on technical development, but rather on fuel markets, the users' acceptance of briquettes as a fuel, other social aspects, as well as resource and environmental impact assessment. In those days Joy Clancy joined our Group and provided important inputs into the resource and environmental assessments. We had to convince our funders and ourselves that the residues which are used for briquetting, would neither be needed nor utilised for fertilising or soil conditioning.

One of the strengths of the Technology and Development Group of Twente University was, and still is, the multi-disciplinary approach of techno-social problems in a development perspective. A strong network of international cooperation was developed, not only with Kasetsart University, but also with IIT, Delhi via Prof. Grover, the Forest Research Institute of Malaysia via Dr. Hoi Why Kong, the then Office of Energy Affairs in The Philippines via Mr. Conrad Heruela, the Consortium on Rural Technologies in Nepal via Mr. Ganesh Ram Shresta, and the Ceylon Electricity Board via the late Mr. Sepalage.

Our project produced lots of documents and the results of the study were presented at a seminar in The Netherlands (Prof. Grover will remember this). The Dutch Government was pleased with the results and was prepared to fund the second phase of the Research Programme, Phase II. This Phase was finally to focus on technical R & D. However, in the mean time we were already into the nineties and the world had changed. Fuel markets in Thailand had developed, and so had the resource supply. Rice husks were no longer available for free. The project approval procedure of the Netherlands Government took another one and a half years, and as time went on it was decided to leave Thailand. The focus of the research shifted to India, as was recommended by the then adviser Mr. Mathew Mendis of the World Bank. The choice was based on an evaluation of the fuelmarket and resource base in India, and I think, also very much on the interest and competence of IIT, Delhi, which was prepared to be the focal point and take the lead in the research programme. It also meant that other biomass residues, including sawdust, became research subjects.

A unique aspect of this phase was, and still is, the four partners in the programme, two in The Netherlands and two in India, that is to say in both countries an academic institute and a private sector company. In the Netherlands it was DENSI-TECH, and in India it was the Solar Sciences Consultancy Pvt Ltd which were selected as the partners. I think experiences of the project have proved that the public/private combination is a healthy structure for such projects and works out well. I happened to be in charge of the project on the Dutch side, and Prof. Prem Grover was in charge on the India side. At this point I would like to thank Prof. Grover for many years of cooperation which I have greatly enjoyed, not only in briquetting but also, for instance, in our project on the Power Guide, together with Joy Clancy. The results of the second briquetting phase will be the subject for discussion in this workshop.

What comes next? Last year, plans were already being developed for a Phase III of Biomass Densification for fuels. This will problably focus on demonstration and implementation of the results in India. I fully sympathise with this plan, but at the same time I regret that other countries in Asia will not be included so as to benefit from the experiences and findings of the previous phases, as was originally anticipated. In my present capacity of Chief Technical Adviser of the FAO-Regional Wood Energy Development Programme in Asia (RWEDP), I have observed that residues and briquetting have an important role to play in some countries in this region. However, adequate technological options are only partly available. I refer to, for instance, Myanmar, Vietnam, part of Lao, Bangladesh, and The Philippines. In the latter country one still gets paid for collecting rice husk from a ricemill, which indicates that there - unlike in Thailand or India - the resource base is abundant. I am delighted that the organisers of the workshop have invited resource persons from some of the named countries. I am sure that experienes of San San Industries in Yangon will be relevant for this expert workshop. RWEDP has also undertaken to sponsor a few observers from its memeber-countries to participate in this workshop. However, these efforts may not be enough. I do think that a specific donor-funded project for international technology transfer and networking in briquetting would be timely and effective.

Mr. Chairman, ladies and gentlemen, I have mentioned already, RWEDP, my new job, since October 1994, made me leave Twente University and join FAO to live in Bangkok. Otherwise I might now be sitting in front of my open fire in Enschede in The Netherlands, where it is still winter, enjoying the warmth provided by Eco-blocks. These blocks are made of densified sawdust and sell well in Europe. In Thailand or India we would rather dream of aircons driven by Eco-blocks--would that be possible?

Mr. Chairman, allow me a few words about the FAO-Regional Wood Engery Development Programme in Asia.

Some of you may know that the RWEDP has been operational for many years, namely since 1983. In the past, RWEDP has already enjoyed cooperation with IIT, Delhi, and I look forward to its continuation. RWEDP is located in Bangkok, and generously funded by The Government of the Netherlands. Last year, the third phase of the programme started. This phase is a substantial programme of 5 years, in which 15 countries in Asia are participating. Altogether these countries are home to more than half of the world's population, and most of them are major woodfuel users. The thrust of the present phase of RWEDP is two-fold:

The first one is consolidating the achievements of the past by disseminating the results and findings to many more people. That means training, workshops, expert consultations etc., both regionally and nationally. It is our aim to have trained more than 2,000 people in various aspects of wood energy development, namely staff from governments and NGOs as well as private sector organisations. Many valuable results from previous studies are still not familiar to people who can benefit from them.

The second thrust of RWEDP is to initiate and support strategies to engage more systematically in wood energy policies and planning. In most countries, efforts have been made by governments and NGOs to relieve pressures on wood energy, however, mostly by small and scattered projects. Often, a larger framework of policy and planning is lacking. The present phase of RWEDP aims to assist the member-countries to firmly incorporate wood energy into national and sub-national energy planning. This can, of course, only be successful with the cooperation of experts from the forestry departments, who have the expertise and background in wood resources. Cooperation with departments for agriculture and rural development and with gender specialists, and others has been instituted. When I refer to RWEDP, I refer basically to 3 specialisms: wood energy resource assessment, wood energy conservation (in this workshop represented by Mr. Auke Koopmans of RWEDP), and wood energy planning. They are all represented in the programme and they are all essential. You will appreciate that the specialisms are not only of a technical/engineering character, as socio-economic aspects are closely interwined with wood energy development. There are many people who earn a living in the wood energy business. There are also numerous people who depend on cheap woodfuels, which are becoming more and more scarce.

The foregoing implies that in wood energy development, we must aim to strike a delicate balance among policies for basic needs satisfaction, environmental concerns, employment and income generation, and balanced rural-urban growth, as well as among other related policy areas. Altogether it makes wood energy development a complex and challenging subject.

When I referred to wood energy, I could have said wood and biomass energy. Even though our focus is on woodfuels, substitution by other biomass fuels is certainly taken into consideration by RWEDP. This can also include briquettes of biomass residues. This is therefore why I personally take both a historical and current interest in the subject of this workshop.

I am looking forward to our further interactions, and I wish you all success in the workshop in the coming days.

## 2.2. Inaugural Address by Mr. B. R. Prabhakara, Secretary, Ministry of Non-Conventional Energy Sources, India

Ladies & Gentlemen,

I am extremely happy to be with you participating in this "International Workshop on Biomass Briquetting".

The topic of the workshop is relevant to our country as over 70% of our population live in rural areas. The most crucial problem we are facing today is that of improving the standard of living and quality of life of the vast majority of our people in rural areas who still live in conditions of want and deprivation. Development has to be accelerated to meet their requirements of basic human needs: food, shelter, clothing as well as for increased income and access to social and cultural facilities. All these require provision of energy in increasing measure for heat, light, electric power, mechanical power and transport requirements.

Primarily, India is an agricultural country. This sector needs all types of infrastructure and support in terms of government policy, technological development and finance. India has always given importance to increasing food production, consequently producing nearly 260 million tonnes of agro-residues per year. These include crop and agro-residues. They are not efficiently utilised and as a result create storage, handling, transportation and pollution problems. In most of the states, these agro residues are burnt loose for small scale energy production. As these residues are not efficient in burning, this adds to the particulate matter in the atmosphere and the smoke created is a pollution hazard. And also in most of the small scale industries, users have preferred wood for their purposes instead of coal because of its cheap price. There is a vast gap of 138.45 MT per year between the demand and formal production. Therefore, vast exploitation of wood in many sectors is the prime cause of destruction of forests. Keeping in view those factors, a technology which can eliminate the inefficient use of present resources, for energy, and reduce dependence on wood and the problems of pollution, needs to be promoted.

Biomass occupies a predominant place as an energy source in rural India. The fuelwood requirement has gone up to around 166 million tonnes per year and the availability has declined to about 28 million tonnes, resulting in a deficit of 138 million tonnes per annum. It has been estimated that India has about 93.69 million hectares of waste lands of which about 20 million hectares is productive non-forest land which would be able to produce 400 million tonnes of fuelwood per year or equivalent to 60,000 MW of power. The Ministry of Non-Conventional Energy Sources has initiated a Biomass Programme with a view to increasing Bio-productivity fast-growing short rotation fuel-wood species, suitable for plantation under the given set of agro-climatic conditions through scientific input and to evolve methodologies/package of practices for increasing the productivity to around 40 tonnes per hectare per year compared to the average forest tree production rate of 0.5 tonnes per hectare per year. Biomass yield ranging from 12 tonnes to 36.8 tonnes per hectare per year have been achieved by the Biomass Research Centres.

The Ministry of Non-Conventional Energy Sources has been supporting a wide range of programmes including research and development, demonstration and commercialistion of various new and renewable energy technologies viz., solar, wind, biomass, small hydro etc. Some of these technologies like wind, solar thermal have reached the stage of commercialisation and the generation of electricity through wind energy has become most competitive with the conventional methods. A target for power generation of 2000 MW through solar, wind, small hydro and biomass has been fixed for the 8th Five Year Plan, which is likely to be achieved. The other important programmes of the Ministry are national programmes on biogas development, national programme of improved chullas, national programme on co-generation etc. Under these programmes, about 12 lakhs family-type biogas plants, 17 million improved chullas, and 1500 biomass gasifiers have been promoted in a rural and semi-rural areas.

The Indian Renewable Energy Development Agency (IREDA), a financing agency under the Ministry of Non-Conventional Energy Sources has been providing soft loans for the installation of new and renewable energy systems. Central government and state governments are providing fiscal incentives to the briquetting industry in the form of customs duty, sales tax, excise duty etc. Presently, about 70 biomass briquetting machines are in the field. Out of these, about 20 machines are financed by IREDA. IREDA has commissioned evaluation studies of the Biomass Briquetting machines which have highlighted the need for improvement through research and development in the Biomass briquetting technology. The R&D areas identified in the reports are characterisation of raw material, improvement in punch & dies and energy consumption. The Ministry of Non-Conventional Energy Sources may provide grants for conducting R&D by the industry to the extent of 50% of the project cost. The industry has to invest 50% of the remaining cost of the project.

Briquetting of biomass carries tremendous scope and potential in converting the agro residues into a more usable form as a fuel. This technology is used to compact the biomass/agro-residues into high density briquettes. This eliminates problems of handling, storage and transportation. The combustion of these briquettes also improves performance as compared to the present utilisation pattern. It is great pleasure on my part to be able to say that IIT, Delhi has contributed towards improving a screw press briquetting technology which is now extensively used in Japan and Europe for making sawdust briquettes. To bring the latest technology from the overseas and then adapt it to the local conditions and utilise local raw materials is the most desirable route for accelerating the development which can utilise local renewable resources in an efficient and environmentally benign manner. I am pleased to learn that IIT Delhi in collaboration with the University of Twente has followed this route. The innovative step of preheating the biomass feed prior to briquetting and trying it with agro-residues thereby improving its performance to the level of making it economically viable is a commendable contribution. Further, I understand that this development has been carried out on behalf of many countries in South and South East countries, which shows our potentials for technology development not only for India but also for other developing countries.

In this workshop, I am happy to learn that greater attention is being paid to exploit the conversion of agro residues to an usable form by using an appropriate technology. Other developed countries have emphasised this kind of technological improvement as well as the conservation of the environment and in this regard have expressed their interest by funding various projects in the developing countries including India. Indeed the interest shown by the Government of Netherlands towards India is unique in nature. At present, they are providing funding in almost each and every sector of non-renewable energy sources. I am glad to be able to report this and definitely this will strengthen the exchange of technological support in the future. I am told that initially under the project activities it was not intended to use rice husk as feed material because of its abrasive nature. But when excellent results were obtained by biomass preheating, and confidence about the reliable operation of the machine was established, trials on rice husk were included. This resulted in proving rice husk as an excellent feedstock for this technology. Rice husk as bio resource for energy has a special interest in Asia where 91% of the world cultivation of rice is carried out and 90 million tonnes of rice husk is generated every year.

Currently in India, piston press machines marketed by different manufacturers are in use for briquetting of biomass. But due to many operational problems, they have never been used to utilize such vast resources of agro-residues presently available in the country. In this context, it is imperative to use a more reliable and up-to-date technology for their efficient conversion on a commercial basis which will in turn improve the country's economic situation. Management of this briquetting sector holds the key to success. Going by observations on investments available and experiences of entrepreneurs in briquetting, it is a matter of concern now. To inculcate awareness of the need for an appropriate briquetting technology and to promote it through proper technological and financial inputs, this workshop is being organised.

Many participants have come for this workshop from South and South East Asian countries who have their own experience in briquetting. I accord them a special welcome and I am very sure that they will not only deliberate on this subject of briquetting, but will critically evaluate the present development of this technology. We look forward to their active participation and recommendations.

Before concluding, I must emphasise that provisions of adequate energy to rural people and also to small scale industries is important in developing countries which are now they are making a transition from a government supported energy infrastructure to a market dominated energy infrastructure. Under market forces, entrepreneurs are required to take the step of adopting these appropriate technologies for renewable energy production. In taking such a step however they will need support from research institutes, technical and financial institutions. This way the change will eventually enable us to meet our growing requirements of energy.

Friends, I have great pleasure in inaugurating this International Workshop on Biomass Briquetting. I am sure it will help us to gain a clearer understanding of the problems involved and the ways to overcome them. I once again extend a warm welcome to the foreign delegates, entrepreneurs, researchers and experts who have come all the way to take active part in this workshop. I wish you all the best.

Thank you.

# 3. BIOMASS BRIQUETTING: TECHNICAL AND FEASIBILITY ANALYSIS UNDER BIOMASS DENSIFICATION RESEARCH PROJECT (PHASE II)

*P.D. Grover, IIT, Delhi, India*

## 3.1. Introduction

Briquetting technology has yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Many operational problems associated with this technology and the quality of raw material are crucial in determining its success for commercialization.

With an objective to improve the technology situation and to investigate the scope for briquetting in South and South East Asia, the Technology and Development Group of the University of Twente was contracted by the Dutch Government's Directorate General of International Cooperation (DGIS) to undertake this task. This resulted in the formulation of a "Biomass Densification Research Project" which was taken up in two phases. Phase I of this project was taken up in 1989-90.

To mitigate the technological and operational problems in briquetting technology, the study in Phase I of BDRP recommended to set up a sponsored project in cooperation with a technical research institute in South or South East Asia and thus formulated the Phase II of "Biomass Densification Research Project".

The objectives of Phase II were:

- To provide manufacturers with an improved technology to turn agricultural and forestry residues into a suitable fuel for industrial and institutional use and export

- Verification of the assumptions made on socio-economic issues during Phase I of the project.

While the former objective about the improvement of the technology was assigned to the Indian Institute of Technology, Delhi, the studies relating to socio-economic issues were assigned to the Tata Energy Research Institute, Delhi.

**Activities in Phase II**

The SHIMADA screw press was used for the Phase II studies. This is unanimously considered to be the best in Japan [2] and is now manufactured in Europe under license. The criteria for selection of the screw press over European ram press were: the quality of briquettes, its compactness, smooth and noiseless operation and virtually free from maintenance except for the wear of the forming screw. Therefore, the reduction of screw wear became the focal aspect of its improvement under Phase II.

The fast and frequent wear of the screw for briquetting of agro-residues increases the cost of production making this technology an uneconomical venture. Therefore, this project is intended to overcome the technological and economic difficulties which will help in the wider dissemination of this technology. The R&D strategy has been to reduce both the wear of the screw due to high friction and the high power consumption. Any savings in power consumption can then be utilized to increase the throughput capacity of the machine and to reduce specific power consumption. The work therefore focussed on optimizing the briquetting process and obtaining performance data on various biomass residues.

To meet these objectives, the machine having a rated capacity of 400 kg/hr was installed and operated at the premises of Solar Sciences Consultancy Pvt. Ltd. at Faridabad. Initial trials were conducted with locally available sawdust. As expected, a very high screw wear was experienced with the screw lasting only two hours. Accordingly, the first approach adopted was to select and try suitable hardfacing alloys on the screw. Having completed this task with a maximum possible life of the screw of 15 hrs, the next approach was to incorporate a well engineered feed preheater into the system. This innovation provided excellent results which were beyond expectations and are comparable to those obtained anywhere in the world with sawdust as feed.

Extensive tests were carried out by briquetting sawdust, rice husk, groundnut shells, coffee husk and mustard stalks. These biomass materials with preheating were studied for the first time for their briquetting in a commercial machine. Though the trials on the most abrasive material, rice husk, was not intended to be the part of the project, in view of its importance, tests were conducted for its successful briquetting. The other biomass residues like bagasse pith, coir pith and tea waste were also tried. The proposal made in the project to incorporate preheating of biomass for reduction of wear of the screw i.e. more screw life, has now become a standard practice. A substantial increase in screw life has been achieved by preheating the raw materials like sawdust and rice husk. The other achievements are gains in terms of power reduction for the screw press extruder and an increase in the rate of production of briquettes. For sawdust, the screw life increased from 15 to 44 hours by preheating it.

## 3.2. Screw Press Technology

The briquetting machine used in this project is a screw extrusion press of the make SHIMADA Europe (model SPMM-850 KS). This extruder has a screw which rotates at a speed of 600 rpm and this compresses the material against a heated die. The die is heated to a temperature of 280-290 $^{0}$C to give smooth extrusion of briquettes. The production capacity of the machine depends on the briquette size. At present briquettes of 55 mm diameter are produced with a rated capacity of 400 kg/hr for sawdust. If a 65 mm diameter die is used then the capacity increases to 600 kg/hr. This factor is important in the financial analysis of the process and influences the selling price of briquettes.

**Briquetting Plant**

The briquetting plant can be operated in two ways. In the first case, while pre-processing the raw material, the temperature of the feed material is not considered. In fact, the temperature is not at all critical for the production of briquettes. But if we take into consideration the power consumption, the wear behavior of the screw and the temperature of the die, then the temperature of the raw material at the time of feeding to the screw extruder plays a significant role. In our case, at the initial stage of the project, the plant was tested without preheating the biomass. In the second phase of development, a preheater was installed to heat the material to study its effect on power consumption and the standing time of the screw against wear.

Material preparation plays a key role in the successful briquetting of biomass. The capacity of the feed preparation section of the plant must match the briquetting capacity of the machine. In the existing plant, the feeding of the raw material to the flash dryer is done through a screw conveyor. Components of a typical flash dryer are an air heater and a fan to produce flow of heated air upwards through a long vertical drying duct. The material to be dried is introduced into the airstream by the feeder, and the hot air conveys the particles through the duct in a concurrent flow. The dried material is then passed through a cyclone to separate particles from air and transported into the collecting hopper. Storage hopper should be given adequate attention regarding its capacity and for very easy-flow of the material. Bridging in the hopper may cause fluctuations in operating conditions and also lead to a hold-up in production. The dry material is then fed to the screw extruder through a screw conveyor for briquetting. In the case of briquetting with preheating of biomass, the material is control fed to a preheater to heat it to a desired temperature. The process flows of a briquetting plant with and without preheater are shown in Figs. 1 & 2. A solid fueled horizontal grate furnace is incorporated into the feed preparation system.

1. Furnace
2. Feeding screw (1 hp)
3. Drier column
4. Drier fan
6. Cyclone for pneumatic conveyor
7. I.D. fan for pneumatic conveyor (3 hp)
8. Air lock
9. Hopper for buffer stock
10. Feeding screw (1 hp)
11. Shimada screw press
12. Agitator (0.5 hp)
13. Shimada main motor
14. Smoke hood
15. I.D. fan (2 hp)

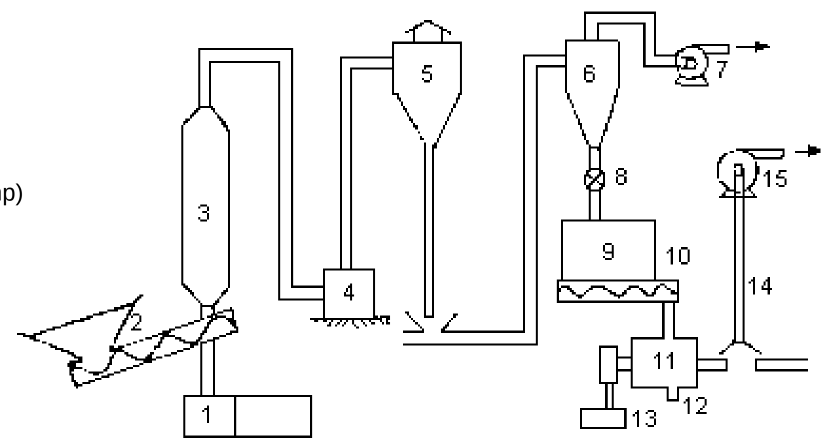


*Fig.1 Briquetting plant flow without preheating*

1. Vibratory screen (0.5 hp)
2. Feed screw (1 hp)
3. Hammer mill (20 hp)
4. I.D. fan (7.5 hp)
5. Air lock (0.5 hp)
6. Horizontal screw with overflow (1 hp)
7. Preheater
8. Shimada screw press (40 hp)
9. Agitator (0.5 hp)
10. Smoke hood (2 hp)
11. Oil pump (5 hp)
12. Oil tank
13. Cooling conveyor (3.5 m)

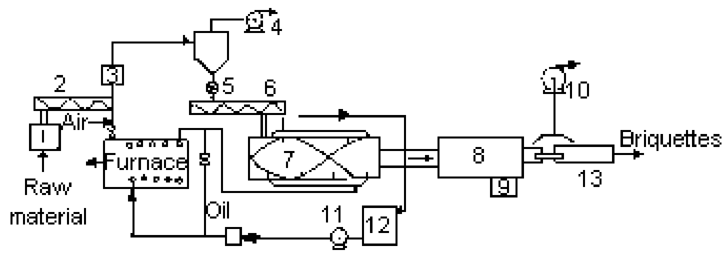


*Fig.2 Briquetting plant flow with feed preheating*

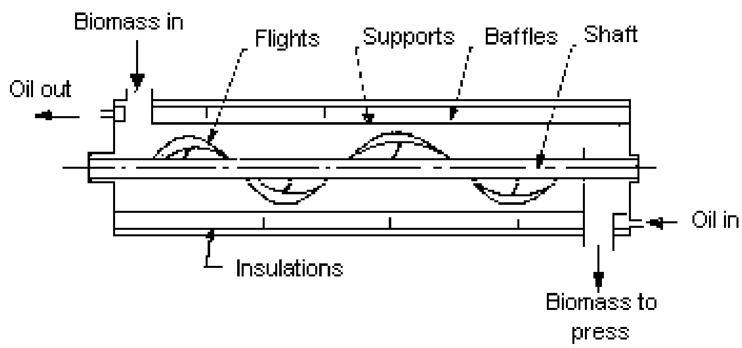


*Fig.3 Schematic diagramatic of a preheater*

Reject briquettes or any other biomass are fired in this furnace and the flue gases diluted with air are used as heating medium in a direct contact flash biomass drier. The same furnace is used to heat commercial grade thermic fluid which is then circulated in the outer jacket of the feed biomass preheater. The normal operating temperature at the outlet to the heater is around 210 $^{0}$C. The preheater (Fig.3) used for this research project is designed to preheat 500 kg/hr of biomass to a desired temperature. This preheater has to deliver 68 kW to the biomass to heat it. The heater in principle is a ribbon paddle conveyor, which mixes and transports the biomass.

## 3.3. Test Program and Results

In order to compare the results with those being attained in Japan and Europe, sawdust was selected as the feed material. The original hardfaced screw supplied with the machine from Europe could not sustain wear for more than three hours and had to be removed for repair. Different hardfacing alloys were then tried and after 10 such trials, a maximum screw life of 17 hours, with a production rate of 340 kg/hr, was achieved by using tungsten carbide as the hardfacing alloy.

Without intending further improvement, it was decided to preheat the sawdust to record its performance. Other raw materials like groundnut shell, coffee husk, rice husk, mustard stalk and bagasse pith were later tried with feed preheating. The total number of hours logged for all the briquetting trials was 760 hours. The performance of the machine with feed preheating on different raw materials is described below.

**Sawdust**

The quality of sawdust locally available is entirely different than that available in Europe or Japan. Firstly, it is mixed due to being produced in small saw mills where it is generated from many hard wood sources. In Europe the sawdust in produced from soft wood. Secondly, it is highly contaminated with extraneous dust, sometimes amounting to as high as 17% by weight (normally this should be between 1-3%). The associated sandy contaminants are highly abrasive and responsible for the short standing life of the screw (3 hours) compared to an average life of 40 hours or so being obtained in Europe. Further, this raw material needs sufficient drying because of its high moisture content of 25-30%.

After drying to 8-10% moisture, the temperature of the sawdust was raised to 80-90 $^{0}$C in the preheater and then briquetted. The temperature could have been more than 100 $^{0}$C but the extrusion was not smooth due to interference of steam with incoming feed. The briquette quality was very good with a smooth surface. The standing screw life increased from 17 hours without preheating to 44 hours with preheating. The production rate also increased from 340 to 360 kg/hr. Another benefit obtained was power reduction by 15-20%. The total number of hours logged with sawdust was 215 without preheating and 210 with preheating.

**Groundnut shells**

It is imperative to grind this material to 6-8 mm size before briquetting. This was grinded in a hammer mill with screen size of 6 mm and then dried. The initial moisture content of the groundnut shell was about 15-16% which did not require much drying. The briquetting of this agro residue was found to be extremely successful and the production rate increased by 20% on the rated capacity of the machine. The groundnut shell can also be briquetted without grinding but the briquette quality will not be very good and the screw will suffer more damage because of the simultaneous action of grinding and pressing. The maximum screw life could not be ascertained because of lack of availability of enough material. However, a standing time of 12 hours for the screw was observed without any damage to the screw flight which is extremely promising.

**Mustard stalks**

These are non-woody biomass with flaky structure which needed grinding before briquetting. Mustard stalk was also found to be an easy material for briquetting after being ground to a suitable size. This also needed drying to get an optimum moisture content of 8-9%. Only 12 hours of run could be obtained because of the limited supply of raw material. In this case also the screw showed no damage after the 12 hours. The power consumption for the machine during briquetting was found to be less (20 kW) than that for groundnut shell. A total of 16 hours of briquetting operations was logged for this material.

**Coffee husk**

Two types of coffee husk are available. The one obtained by the traditional dry process is brown in colour and also contains remnants of dried cherry pulp. The white parchment type is obtained by the wet process. Both these types were tried for briquetting in separate runs and were not suitable for briquetting in their raw form. Being an easily decomposable material heat produced during grinding prior to briquetting by screw resulted in the evolution of volatiles near the feed end of the screw. These volatiles, along with steam, interfered with the inflow of material and formed lumps of feed material. This resulted in a lowering of the production rate and, finally, jamming of the machine. This operational bottleneck was removed by crushing the material to a bulk density of about 0.275 g/cm$^3$ from the original bulk density of 0.18 g/cm$^3$.

The ground material showed excellent briquetting characteristics and the quality of briquettes in terms of strength was very good. The briquetting of coffee husk almost gave a 60% increase in the rated production and consumed only 18 kW power for the extruder. The screw was found to be in good condition even after a run of 27 hrs which produced nearly 18 tonnes of briquettes. The total number of hours logged with coffee husk was 43 hours. Coffee husk was supplied by M/s Aspinwal & Co., Mangalore who are planning to set up a briquetting plant with two machines.

**Rice husk**

The very first run was carried out on unground rice husk using the hardfaced original European screw supplied with the machine. This screw could not give production for more than 20 minutes and extensive damage to the first flight of the screw was noticed.

The latter tests with rice husk were conducted after grinding the material to 8 mm maximum size and with a bulk density of 0.275 g/cm$^3$ and preheating it to 90-95 $^0$C. The original bulk density of rice husk was 0.12 g/cm$^3$. The total number of hours logged with rice husk was 215 hours. The screw standing life was 31 hours at the production rate of 500 kg/hr.

**Bagasse pith**

Pith comprises very fine particles (< 2 mm) in sugarcane milled bagasse, which has to be removed before bagasse is used for making paper and paper boards. It also contains 35-50% moisture when a dry de-pithing operation is carried out. About 30% pith is recovered which forms a substantial quantity and does not entail collection problems. For 100 TPD paper mill the same amount of pith is generated everyday. Being fibrous in nature it is devoid of lignin and hence considered unsuitable for binderless briquetting. The bulk density of dry material is also as low as 0.067 $g/cm^3$. Operational experience gained with briquetting of bagasse pith indicated that it is not possible to briquette this material as such.

Trials made with pith resulted in intermittent production of briquettes with poor quality and very low production rate. However, when pith was mixed with ground rice husk in equal proportions the quality of briquettes were very good with a smooth surface and good strength. The production rate obtained was only 320 kg/hr which was lower than the rated capacity of the machine of 400 kg/hr. Due to a limited supply only 5 hours was logged with pith.

**Additional feeds**

During the course of the present project many agro-based industries indicated their interest in considering briquetting technology as a possible route for utilization of their captive waste materials. Accordingly, we got limited supply of decaffeinated tea waste from Assam, tobacco waste from I.T.C., Guntur (Andhra Pradesh) and coir waste all the way from Tamilnadu. Coir waste produced good quality briquettes but due to limited availability of raw material it is impossible to make any other conclusion. Decaffeinated tea waste is an absolute waste from an industry engaged in the recovery of natural caffeine from tea wastes. During extraction of the caffeine, amounting to 2% of feed weight, the feed is mixed with 25% lime which finds its way into the spent waste. Briquetting of decaffeinated tea waste did not produce good briquettes. However, when it was admixed with 50% rice husk, the standard type of briquettes were produced. The experience with briquetting of these industrial wastes indicates that with proper formulation, briquettes of good quality can be obtained with a screw press.

Table 1 shows the effects different biomass on screw life and the corresponding tonnage of briquettes produced.

*Table 1. Data on briquetting of different preheated biomass*

| Biomass | Screw life (hrs) | *Production rate (kg/hr) | Tonnage produced | Need to repair |
|---|---|---|---|---|
| Sawdust | 44 | 360 | 15.84 | yes |
| Rice husk (ground) | 31 | 500 | 15.50 | yes |
| Mustard stalks (ground) | 12 (ic) | 360 | 4.32 | no |
| Groundnut shells (ground) | 12 (ic) | 480 | 5.76 | no |
| Coffee husks (ground) | 27 (ic) | 600 | 16.20 | no |

ic: test is incomplete
* rated production capacity of the machine = 400 kg/hr

## 3.4. Project Outcomes - Facilitating Commercialization

The commercial exploitation of the technology tested under this project depends on the following key factors: cost of raw material, cost of power, rebuilding cost of the screw, and acceptance of briquettes on an economic basis. The economic success of any briquetting plant however also depends upon the scale of operation, capacity utilization and efficient management. As to how these key factors were addressed by the activities of the project are now discussed.

**Cost of raw material**

Given the agricultural nature of the Indian economy, the agro-residues definitely hold a potential for briquetting but their cost is indicative of the final cost of the briquettes. To draw a general conclusion on this point is difficult due to the size of the country with such diverse geographical areas and different operating climates, which lead to wide variations in raw material prices and transport costs. Therefore, a financial analysis of this technology involving a particular raw material is highly site specific. Further, prices of raw material are governed by the price of coal in any location which in turn shall control the sale price of briquettes. Depending upon the locations, the prices of raw material vary from Rs. 400 to Rs. 1000 per tonne. Based on these prices, the sale price of briquettes has to be Rs. 1200 to Rs. 1800 per tonne to make the project economically viable.

Further, this technology, though rural based, has to function as an industrial unit within the small scale sector with proper inputs of industrial and financial management. Therefore, it is more suited for agro-processing industries which generate their own captive raw materials and have an added advantage of saving substantially on the transportation cost of raw materials. It is equally beneficial to those who have a large captive consumption of briquettes and are presently using agro-residues with low utilization efficiencies and/or expensive coal.

**Cost of power**

Specific energy consumption is another important factor for the economical production of briquettes. Firstly, thermal energy may be required to lower the moisture content. Secondly, mechanical energy may be required to grind the raw material into smaller particle sizes. Thirdly, the screw press must be powered which requires mechanical energy, and it also needs power for die heating. The auxiliary equipment such as material handling and feeding devices also need power. Together, these energy requirements may play a significant role in determining the feasibility of a briquetting project. The energy needs for drying and milling depend on the type of raw material used.

One of the positive contributions of this project is the reduction of specific power consumption. By incorporation of feed preheating, specific power consumption has been reduced from 70 to 40-55 kW/tonne depending upon the type of raw material used. A reduction of power consumption by 21-42% is substantial, thus making a positive contribution towards making briquetting economical. In addition to power required for electric motors, 5 kW of electrical heaters are also employed to heat the die. It has been observed that the heaters are normally off during the smooth operation when preheated feed is used. This provides an additional power reduction amounting to 2.5 kW/tonne. However, the same order of extra power is needed to operate the preheating system comprising of a circulating pump for thermic fluid and a feed preheater. In short, no additional power consumption is required when the preheater is used.

Depending upon whether the material requires grinding or drying or both, the overall power consumption in the plant varies from 50-75 kW/tonne of production. Table 2 gives production rates obtained with preheating and specific power consumption for different biomass.

*Table 2. Data available on different preheated biomass*

| Raw material | Specific power consumption in machine (kWh/tonne) | *Production rate (kg/hr) | Higher calorific value of briquette (kcal/kg) |
|---|---|---|---|
| Sawdust | 45 | 360 | 4420 |
| Rice husk (ground) | 55 | 500 | 3200 |
| Groundnut shells(ground) | 45 | 480 | 4500 |
| Mustard stalks (ground) | 45 | 360 | 3800 |
| Coffee husk (ground) | 30 | 600 | 4300 |

* rated production capacity = 400 kg/hr

**Rebuilding cost of screw**

The major contribution of the project was to extend the life of the screw to the same level as obtained in Europe with soft sawdust. Many hardfacing alloys were tried during the course of operation with this machine. The details of the various alloys used and the corresponding standing life of the screw obtained are discussed below.

Initially the screw was giving a screw life of not more than 4 hours by using an iron based hardfacing alloy (6006 and 6715 by L&T). Then cobalt based deposits (9120 N and 9080 N by L&T) were tried which also miserably failed by giving a screw life of only 2 hours. These trials were made without preheating of the biomass. After testing some other hardfacing alloys, tungsten carbide was applied which improved the screw life to 17 hours. Several runs were made with this deposit but no improvement was observed above 17 hours. Then briquetting was carried out with the heating of sawdust to 80-120 $^{0}$C prior to its briquetting. This substantially improved the screw life to 44 hours by applying tungsten carbide on the screw flight. All these runs were made using sawdust as the briquetting material. The concept of preheating proved to be successful for other raw materials as well like rice husk, mustard stalks, groundnut shells, coffee husk etc. Even using rice husk, the most abrasive raw material, the screw life increased from 20 minutes to 31 hours by grinding and preheating the raw material and using tungsten carbide on the screw. Table 3 gives the rebuilding cost of the screw using different hardfacing alloys. The results show that the cost of rebuilding the screw has been brought down from Rs. 650 to Rs. 150 by selecting suitable alloy and then from Rs. 150 to Rs. 30 per tonne of briquettes by incorporation of the biomass preheating system. This reduction in cost in addition to the cost of power reduction are the two overriding factors in establishing the economic viability of this technology in India.

*Table 3. Performance of various hardfacing alloys*

| Hardfacing alloy (L&T) | Rebuilding cost (Rs.) | Screw life (hrs) | Cost/tonne (Rs.) |
|---|---|---|---|
| Sawdust without preheating: | | | |
| Chromcarb 6006 | 600-800 | 4 | 583 |
| AbraTech 6715 N | 800 | 4 | 666 |
| Eutecdur 9120 N | 1000-1200 | 1.5 | 2666 |
| Eutecdur 9080 N | 1500-2000 | 2 | 3333 |
| EWAC 1001 EB Ni-Cr powder | 600 | 4-5 | 400 |
| Ultimium N 112 (Tungsten carbide) | 700 | 17 | 150 |
| Sawdust with preheating: | | | |
| Ultimium N 112 | 500 | 44 | 32 |
| Rice husk with preheating: | | | |
| Ultimium N 112 | 500 | 31 | 30 |

The additional capital cost involved for the installation of a preheating system for a 30 TPD plant is about 6.0 lac. With the operational cost savings of Rs. 160 per tonne in reduction of power and maintenance of the screw, the additional capital invested should be recovered by producing 3,750 tonnes of briquettes or within 125 days of operation. This will, of course, be more favorable for plants of higher capacity.

## 3.5. Conclusions

! Studies so far undertaken conclude that a large potential exists for briquetting in India.

! The concept of preheating of agro-residues was found to be successful in increasing the screw life, reducing the power consumption and increasing the production rate. This must be incorporated into commercial plants.

! Broad economic analysis undertaken concludes that the minimum standing life of the screw should be 24 hours for its rated capacity i.e. 9.6 tonnes of briquettes should be produced before the screw is taken out for repair. The present studies have given 17 tonnes of briquettes. These plants are economically feasible with a minimum of two machines.

! The actual availability of various raw materials in and around the plant should be ascertained before setting up a briquetting plant.

## 3.6. References


- Biomass Densification Research Program, Volume A, B, C, Technology and Development Group, University of Twente, The Netherlands, 1990.
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# 4. BRIQUETTING OF BIOMASS IN INDIA - STATUS AND POTENTIAL

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## 4.1. Findings

### Location of plants

At present more than 60% of the briquetting plants are located in the states of Gujarat, Punjab and Tamil Nadu, about 30% plants are located in Uttar Pradesh, Maharashtra and Karnataka and rest in Madhya Pradesh and Andhra Pradesh. The state-wise break-down of briquetting units covered under the present study is given in Table 1.

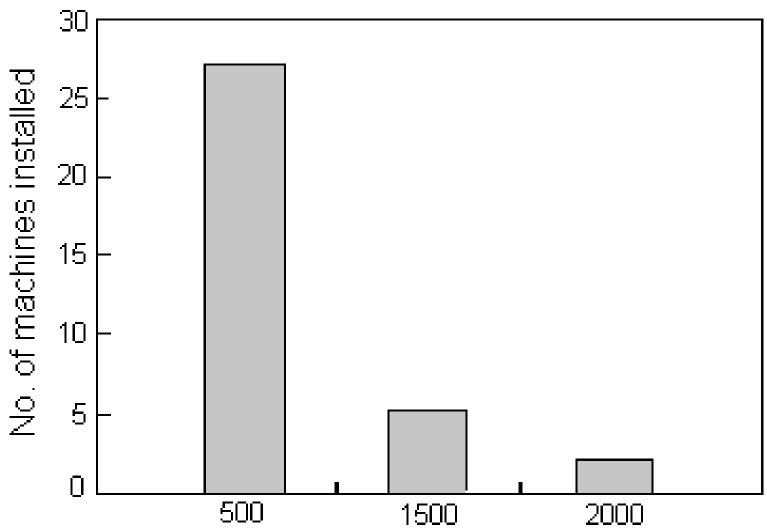
*Table 1. State-wise break-down of briquetting units covered*

| State | Preliminary questionnaire | | Detailed questionnaire | | No. of units visited |
|---|---|---|---|---|---|
| | No. of units covered | No. of responses received | No. of units covered | No. of responses received | |
| Uttar Pradesh | 3 | 2 | 2 | 2 | 1 |
| Punjab | 5 | 2 | 2 | 1 | - |
| Gujarat | 8 | 5 | 8 | 5 | 5 |
| Maharashtra | 3 | 2 | 2 | 2 | 2 |
| Madhya Pradesh | 1 | 1 | 1 | 1 | - |
| Karnataka | 3 | 1 | 2 | 1 | 1 |
| Tamil Nadu | 5 | 3 | 4 | 3 | 2 |
| Andhra Pradesh | 1 | - | - | - | - |
| Total | 29 | 16 | 21 | 15 | 11 |

### Plant Profile

Depending on the nature of the raw material the following pre-processing is required for briquetting: (i) Drying and (ii) Chopping/pulverizing. Size reduction of the raw material is done by chopping and by a hammer mill pulverizer. The capacity of the hammer mill is 1 ton/hr and its power requirement is about 40 HP. Drying of the raw material is often required and can be done by open sun drying or with a hot air drier. About 10% of the briquettes are consumed in the drier to bring down the moisture content of biomass from 25% to 10%. Briquette manufacturers generally prefer raw materials requiring minimum pre-processing. In India, all the existing commercial high density briquetting plants use piston extrusion machines. The present capacity of the individual machine ranges from 500-2000 kg/hr.

Fig.1 shows the distribution of the number of machines in each capacity range. It can be observed that briquette manufacturers prefer to install a number of machines of 500 kg/hr capacity rather than install one single machine of a higher capacity. Among the briquetting machines covered by the study, more than 65% of those installed in the field were supplied by the M/s Solar Sciences Consultancy Pvt. Ltd. and the rest by other manufacturers.




Briquetting capacity m/c (kg/hr)

*Fig.1. Distribution of briquetting plants in different capacity ranges*

**Raw material supply**

Residues such as sawdust, coffee husk, rice husk are in a ready-to-use form. Other residues such as mustard stalk, cotton stalk, groundnut shell etc. can be briquetted after grinding. The raw materials used for briquetting vary in different parts of the country. In the western part of India the primary raw materials used are sawdust, groundnut shell and cotton stalk. In the northern region sawdust and mustard stalks are the primary raw materials while in the southern region groundnut shell, sawdust, coffee husk and tamarind husk are used. It has been observed that each briquetting entrepreneur has adopted his own combination of residues owing to technical and economic reasons. In some units, a shift from one type of residue to other has also happened because of economic considerations. By and large, the existing briquetting plants seem to rely mainly on selective "mill residues" such as sawdust, groundnut shell etc., which are available in bulk quantities at reasonable prices rather than field residues, as the logistics of harvesting field residues have not been established so far. The prices of several residues compiled from responses to questionnaires are given in Table 2.

*Table 2. Prices of various crop residues*

| Residue | Cost (Rs/ton) | Comments |
|---|---|---|
| Sawdust | 400-600 | |
| Coffee husk | 450-600 | |
| Bagasse | 250-350 | requires drying |
| Rice husk | 450-600 | rarely used by few units |
| Tamarind husk | 250-350 | |
| Coir pith | 300-350 | |
| Groundnut shell | 450-550 | |
| Cotton stalks | 400-450 | requires chopping and pulverizing |

The transportation costs of various raw materials are compiled in Table 3 from data collected in the field study.

*Table 3. Transportation cost (Rs/ton)*

| Raw material | 0-10 km | 10-30 km | 100-200 km | > 200 km |
|---|---|---|---|---|
| Sawdust | 75 | 100 | 150 | 200 |
| Groundnut shell | - | 100 | 150 | 200 |
| Cotton stalk | 75 | 100 | - | - |
| Mustard stalk | 75 | 100 | - | - |
| Coffee husk | - | 175 | 200 | 250 |
| Coir pith | - | 75 | 100 | - |
| Rice husk | 100 | 150 | - | - |
| Bagasse | - | - | 150 | 200 |

Truck Load: 8 to 9 tonnes briquettes, 1 to 2 tonne raw material
Tractor Load: 4 tonnes briquettes, 0.5 to 0.75 tonne raw material

It appears that for some cases, raw materials are transported over long distances. Probably such units were established based on "assumed" figures for raw material availability, prices etc. and in due course the assumptions were proven wrong. The peak working seasons of major agro-industries are shown in Table 4.

*Table 4. Peak working seasons of major agro-industries in India (NPC, 1987)*

| Type of unit | Working season |
|---|---|
| Rice mill | Mid October to April |
| Sugar mill | January to June |
| Groundnut oil mill | Mid November to Mid August |
| Cotton ginning mill | January to May |
| Saw mill | All year |
| Jute mill | Mid November to June |

## 4.2. Techno-Economics of Briquette Production

In biomass briquetting technologies there are several operational problems related to wear and tear of machine parts. As a result, the average capacity utilization of briquetting machines is low at about 28%. However, the existing costs of procurement and briquetting of biomass allow entrepreneurs to manufacture and sell briquettes at prices competitive to commercial solid fuels such as coal and leco. Conversion of briquettes into producer gas has been shown to be viable, and if this technology could be promoted, briquettes can compete with fuels such as charcoal, LPG, LDO and furnace oil, thus enhancing the potential of biomass briquetting. The various costs which decide the selling price of briquettes are shown in Table 5.

*Table 5. Break-down of costs of production for briquettes*

| Manufacturer | Cost (Rs./ton) of briquettes produced | | | | |
|---|---|---|---|---|---|
| | Raw material | Transportation | Power & labour | Maintenance & repair | Marketing |
| A. | 400 | 75 | 400 | 200 | 50 |
| B. | 400 | 100 | 250 | 75 | 75 |
| C. | 350 | 75 | 300 | 150 | 20 |
| D. | 500 | 100 | 200 | 100 | 50 |
| E. | 400 | 100 | 300 | 150 | 100 |
| F. | 400 | 200 | 200 | 100 | 100 |
| G. | 300 | 100 | 270 | 80 | 100 |

It can be seen that briquettes can be sold at prices varying from Rs. 1200 to 1500 per tonne, where as the price of coal or leco in these regions is about Rs. 2,000 per tonne.

## 4.3. Briquette Use - Present and Future Perspectives

The current major users of briquettes in various regions are shown in Table 6. The survey revealed that there are no major problems at present as far as marketing of briquettes is concerned. In fact, the demand for briquettes far exceeds the supply at present, either due to high prices or due to shortage of commercial fuels. However, usage of briquettes is not without its problems. The equipment used to burn biomass briquettes is not designed for such use.

*Table 6. Potential users of briquettes*

| State | Type of industry | Briquettes used as replacement for |
|---|---|---|
| Uttar Pradesh | Leather industry, Brick kiln | Coal |
| Punjab | Solvent extraction oil mill, Brick kiln | Coal |
| Gujarat | Textile, Dye and chemical industry | Coal |
| Tamil Nadu/Kerala/ Karnataka | Tea factories<br>Rubber factories<br>Pharmaceutical industries | Wood, Leco<br>Leco<br>Coal |
| Madhya Pradesh/ Maharashtra | Textile industry, Pharmaceutical industries, Brick kiln | Coal |

Briquettes in general have more volatile matter and hence the combustion equipment should be either designed or retrofitted to burn briquettes efficiently. One user of briquettes for a rubber retreading factory reported higher fuel costs per unit of output, indicating a lower thermal efficiency of the boiler, as the calorific values of briquettes and coal are comparable. It is thus desirable to perform comprehensive energy audits for the various briquette using equipment. The other problem reported is that of slag formation. Briquettes have the tendency to disintegrate during combustion thus aiding slag formation. This phenomenon was observed in the gasifiers at TERI also and has to be solved effectively.

Biomass briquettes had earlier been considered as substitutes primarily for fuel wood used in applications such as rural industries, brick kilns, tobacco curing, and silk reeling. The present study, however, reveals that the prices of briquettes will be considerably higher than those of traditional biomass fuels like rice husk, fuel wood, corn cobs, ground nut shells etc. which are commonly used in rural and semi-urban industries. Hence briquettes may not be able to replace these fuels in a significant way. Due to the same reason, briquettes can not also replace biofuels used in domestic sector for cooking, water heating etc.. It has, however, been shown that briquettes can be gasified and the gas can be used to replace petroleum fuels like LPG, LDO and furnace oil. A lime line owner in Haryana tried to use briquettes as replacement in a charcoal gasifier but reported higher tar and dust contents in the gas which was not acceptable. Hence, there is a strong need to develop specific technology packages for specific end user based on gasification of briquettes. The energy cost per unit of useful energy delivered, for any fuel can be written as:

$$\text{Energy cost (Rs/kg)} = \frac{\text{Fuel cost (Rs/kg)}}{\text{Calorific value (kJ/kg)} \times \text{Efficiency}}$$

The energy costs calculated from the above equation are shown in Table 7. It can be seen from Table 7 that energy cost of solid and liquid fuel is much lower than that of gaseous fuels. Among solid fuels biomass briquettes are cost competitive with other fuels. The energy cost of producer gas obtained from briquettes compares, in economic terms, favourably even with petroleum fuels.

*Table 7. Cost of thermal energy for various fuels*

| Fuel | Fuel cost (Rs/Kg) | Calorific value (KJ/Kg) | Efficiency (%) | Energy cost (Rs/GJ) |
|---|---|---|---|---|
| Coal | 1.5 | 17556 | 60 | 142 |
| Leco | 2.5 | 26125 | 60 | 150 |
| Firewood | 0.9 | 12540 | 60 | 120 |
| Briquettes | 1.3 | 18810 | 60 | 115 |
| LPG | 6.5 | 48664 | 55 | 245 |
| Furnace oil/LDO | 7 | 43639 | 90 | 111 |
| Producer gas (briquette) | 0.6* | 4606* | 55 | 236 |

* values are per $Nm^3$

## 4.4. R & D Needs

The study reveals that in India at present, the degree of technological maturity is not yet high, as indicated by the low capacity utilization of the installed plants. A study conducted concurrently at the Indian Institute of Technology, Delhi showed that heating of biomass prior to briquetting not only improves the life of machine parts, but also reduces specific power consumption. The effect of temperature on the quality of briquettes produced should be studied. Energy audits of combustion equipment using briquettes in place of other solid fuels should be a carried out and suitable retrofits should be developed to optimize the efficiency of the system for briquette use. Gasification of biomass briquettes should be researched further so as to develop specific application packages for different industries using petroleum fuels. Another important concept is to develop the existing briquetting plants into biomass based decentralized power plants for rural electrification. The major drawback of biomass based power plants so far has been the difficulty of procuring biomass on a sustainable basis. The entrepreneurs who established briquetting plants in remote rural areas have, to a large extent, solved the problem of biomass procurement.

A briquetting plant employing even a single machine of capacity 500 kg/hr can sustain a power plant of about 400 kW at full load. Calculations show that the cost of electricity generated from biomass gasifier-based diesel power plants is low compared to photovoltaic or wind generated electricity.

# 5. EFFECT OF FEED PREHEATING ON BRIQUETTING OF DIFFERENT BIOMASS

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## 5.1. Introduction

The briquetting of biomass has so far posed different problems in different kinds of machines and remains yet to establish a standard procedure for each biomass. The main reason is the changing physico-chemical characteristics of different biomass under different conditions. For the purpose of large scale commercialization, it is highly essential to study the behaviour of each biomass for its application in briquetting. For many years, methods of briquetting have been investigated and it is an established fact that typically very high power levels are required to form stable high density aggregates. This is true for piston, screw and roller type extrusion processes. This high pressure amounts to high electrical energy consumption and high wear rate of machine parts. Some of the studies [1,2,3] made earlier have revealed that the addition of heat benefits by relaxing the inherent fibers in biomass and apparently softening its structure resulting in release of some bonding or glueing agent on to the surface. Reed et al [4] have also observed in laboratory scale experiments that the work requirement for densification can be reduced by a factor of about two by preheating the raw material. The results reported by Sayed et al [5] have established that the preheating lowers the power input. They have studied power consumption in the screw press briquetting of preheated sawdust at different die temperatures.

This paper sets out to examine the role of biomass preheating under continuous extrusion in a screw press by using data from laboratory experiments in a hydraulic press using different biomass like sawdust, rice husk, groundnut shells, mustard stalks and coffe husk.

## 5.2. Equipment and Procedure

The laboratory equipment used to form the briquette consisted of a vertical 5 tonne hydraulic press for applying load and a die of 5 cm internal diameter x 16 cm length in which the briquette was formed. This die section had an outer heating element - thermostatically controlled and surrounding the forming die, which allowed the die temperature and consequently the raw material temperature to be increased. Thermocouples were used to measure the material temperature.

For each experiment the die was filled with a sample and heated to the desired temperature. The hydraulic ram was then forced into the die to make a single briquette. The maximum distance travelled by the ram was noted for different pressures and this was used to calculate the increase in bulk density of the material. The moisture content has a very important influence on the process of briquetting as well as the quality of briquettes, but in this research the role of temperature is emphasised. Accordingly, all the samples under consideration were oven dried. For the biomass saw dust, rice husk, groundnut shells, coffee husk and mustard stalks results have been obtained at different temperature levels of 60 $^0$C, 80 $^0$C, 100 $^0$C, 120 $^0$C and varying the load from 1 to 5 tonnes. In a screw extrusion process, a 400 kg/hr Shimada machine [6] was used for the briquetting operation. The preheating temperature of biomass was obtained by a horizontal and jacketed agitating conveying system and hot thermic fluid was circulated in the jacket as a heating medium.

## 5.3. Results and Discussion

It is obvious that for any material, an increase in pressure at any level of temperature will result in the bulk density also increasing. But it is interesting to obtain an increase in bulk density with an increase in temperature under the same load in a hydraulic press and also corresponding data of increased production with the same density in an industrial briquetting machine.

**Hydraulic Press**

In this research, when various biomass types were subjected to different temperatures and pressure conditions in a hydraulic press, the density of the final briquette was found to vary (Figs. 1 to 5).

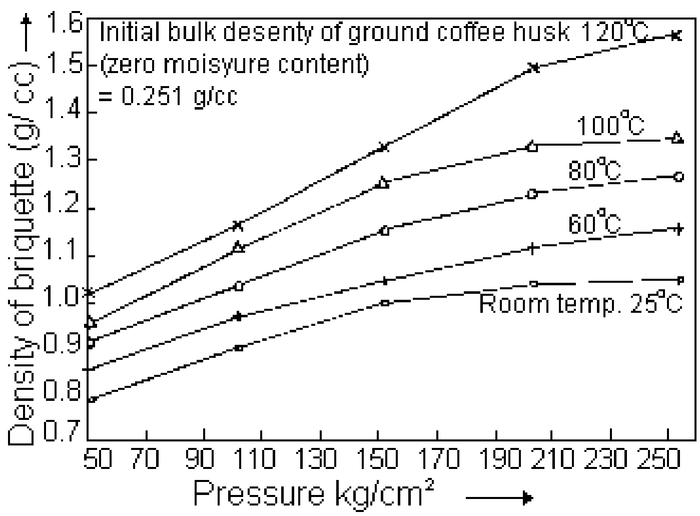


*Fig.1 Variation of density with pressure at different temperatures for coffee husk*

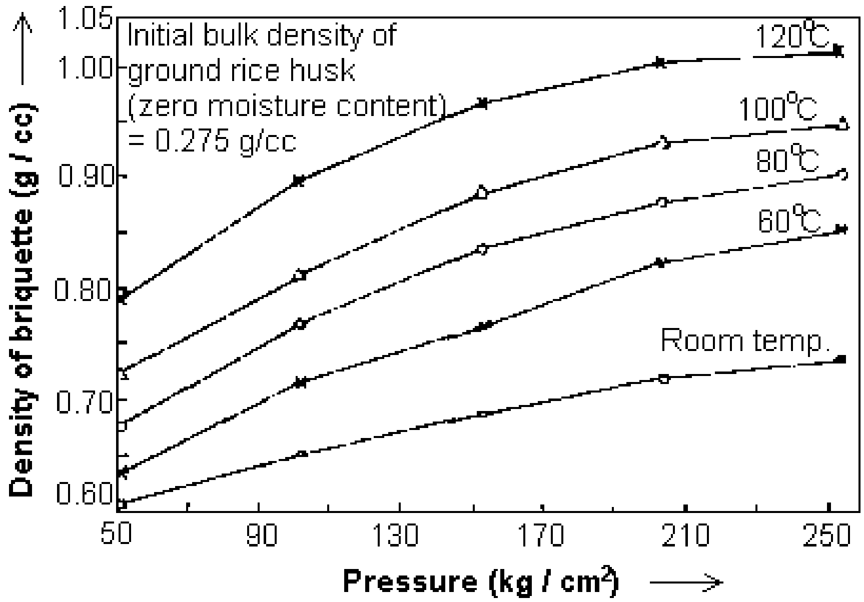


*Fig.2 Variation of density with pressure at different temperatures for ground rice husk*

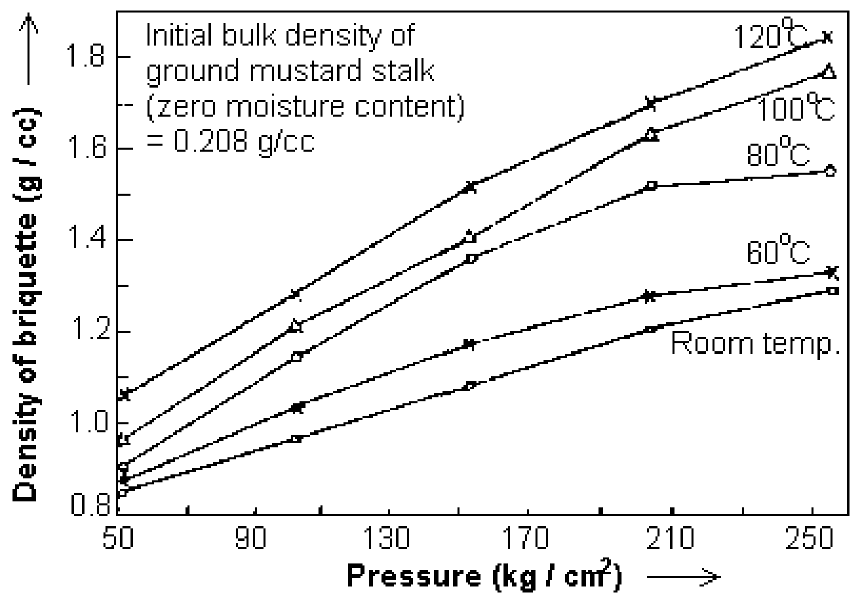


*Fig.3 Variation of density with pressure at different temperatures for mustard stalk*

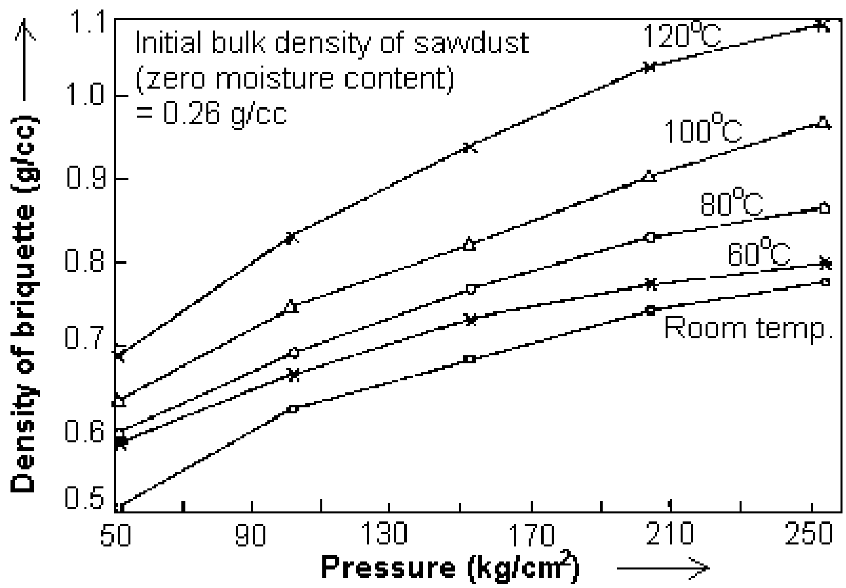


*Fig.4 Variation of density with pressure at different temperatures for sawdust*

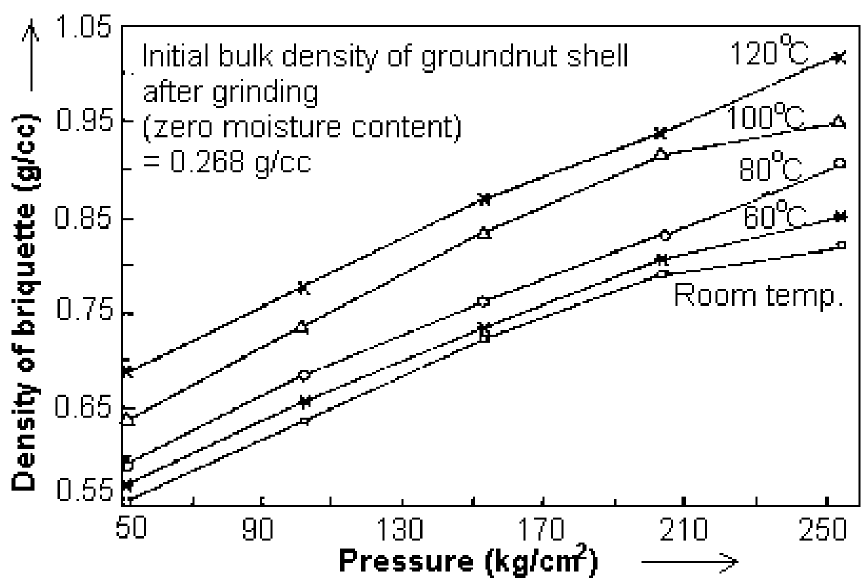


*Fig.5 Variation of density with pressure at different temperatures for g.n. shell(grinded)*

Before conducting the experiments, each biomass underwent a sieve analysis. This showed that the maximum size particle of present in each sample was 6 mm which is suitable for briquetting. The particle size is important because there is an optimum initial density or charge size for a given diameter of die. Above the optimum size, the binding pressure is no longer fully transmitted to the whole bulk of the compressed material. The size also ultimately affects the final density of the briquette. Under the investigations described here, tests were carried out by varying the temperature upto 120 $^0$C.

Edwards et al [7] have found that the specific gravity of western hemlock sawdust increased with increasing temperature with the maximum occurring at 190 $^0$C for most pressures. Specific gravity decreased at the highest temperature because of charring. They also found that the effect of pressure was relatively small when temperature was 120 $^0$C or more. Figs. 1 to 5 clearly show a consistent improvement in bulk density which means an increase in compression ratio and as a result of which the density of the briquette increases giving it a better strength. But the trend of improvement in bulk density is not similar for all biomass at all temperatures. Our results show that maximum increase in bulk density is obtained for mustard stalks but it is less with sawdust and groundnut shell compared to the former.

This can be seen in Fig.6 where the bulk density of the mustard stalk increased by 8.9 times when subjected to a temperature of 120 $^0$C under a load of 5 tonnes (254.71 kg/cm$^2$). This describes the fact that with an increase in temperature the resistance of the material decreases against an applied load by giving a better compaction. But the decrease in resistance of material is not the same for all kinds of materials. For example, in the case of sawdust, rice husk and groundnut shell the change is gradual with an increase in temperature (Fig. 6). One important observation can also be made from the figures 1 to 5, that a combination of high temperature and less load, and low temperature and high load exists for a particular value of bulk density for all the materials. This indicates that a biomass heated to a high temperature will take less load for a desired compaction level. This will help in reducing the power consumption as well. Thus, a high pressure compacting machine can operate at a lesser load resulting in less wear and tear of the contact parts. As different biomass behaves differently under varying conditions, it is desirable to predict the conditions for briquetting of each biomass to save the extra load.

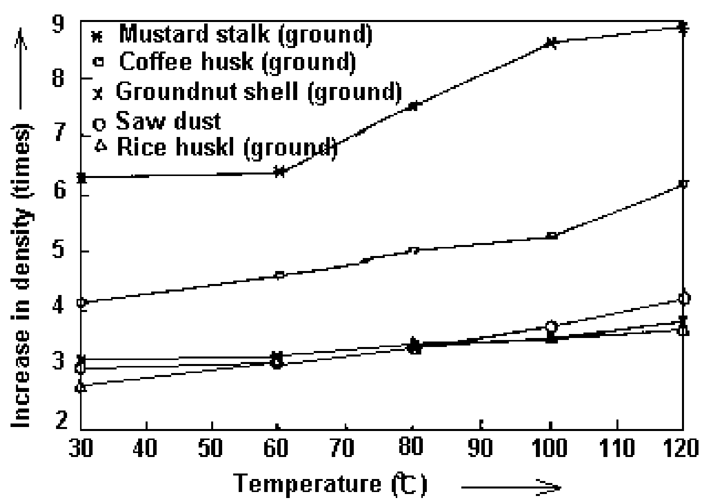


*Fig.6 Increase in density with increase in temp. for diff. materials under a load of 5 tons*

By observing the change in bulk density with the temperature of the raw material from Fig. 6 it is suggested that coffee husk and mustard stalks be heated to more than 100 $^0$C, whereas sawdust, groundnut shells and rice husk can be heated to below 100 $^0$C to get maximum benefit from pre-heating.

**Screw Extrusion**

This test for different biomass consisted of a Shimada screw press, a thermic fluid heater, a flash drier, a screw feeder and a blower. After drying the material it was fed to one end of the preheater where hot oil was circulated to heat the biomass. The heated raw material discharging from the other end of the preheater was then directly fed into the screw press where good quality briquettes were obtained through a heated die. The pressure exerted by the extruder could not be varied because of its inherent characteristics. However, the desired temperature of the raw material was attained by using a thermic fluid preheater. The experiments conducted here cannot be compared with the results obtained from the previous experiments because in the latter case moisture content also plays a significant role. But the results obtained definitely showed power reduction with the preheating of the raw material. Maximum power reduction of 15-20% for the machine was observed using dried sawdust (8-10% moisture) at a temperature of 90 $^0$C. If the same moisture content is maintained, the power reduction can be observed for groundnut shells, coffee husk and mustard stalks. Rice husk does not fall into this category because its initial moisture content is around 7-8%. The moisture content still reduces with preheating. It is well known for a screw extruder using a heated die that an optimum moisture content is required for the smooth production of briquettes. Therefore in the case of rice husk power reduction is not important but the high temperature of the material helps in softening it which is responsible for less wear of the screw.

The production rate of the briquettes also increased with preheating (Table 1).

*Table 1. Data available on different preheated biomass*

| Raw material | *Production rate (kg/hr) |
|---|---|
| Rice husk (ground) | 480-540 |
| Groundnut shells (ground) | 480 |
| Coffee husk (ground) | 600-700 |

* at a rated capacity of 400 kg/hr

For sawdust, the screw life increased from 17 to 44 hours by incorporating heating. Another benefit from preheating of raw material is that the die temperature that is required for briquetting of biomass at room temperature can be decreased when the raw material is hot. The results obtained so far indicate that for maximum benefits that material should be preheated. In a screw extrusion press, the screw used for briquetting takes the maximum load. Because of the effective load reduction, the screw life also increased for each biomass. In the past the screw repair cost was very high and now as the standing time of the screw increased, the repair cost has reduced to a considerably low level when compared on a per tonne basis. For the most damaging material like rice husk, screw life increased to 31 hours with preheating which was not even an hour. This has encouraged the use of a preheater in a briquetting plant to make it more cost effective.

## 5.4. Conclusions

- Preheating causes a reduction in power consumption (15-20%) which is highly beneficial in terms of economics.
- The smaller load required with preheating the raw material will cause less damage to the machine parts.
- Different temperatures and pressure conditions can be predicted for different biomass.
- Since the production rate increases with preheating, the electrical energy consumption will be reduced on a per tonne basis. Therefore, a preheating system must be included in the briquetting process so that it can produce at the high rate needed in a briquetting plant.

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# 6. BIOMASS BRIQUETTING - AN INDIAN PERSPECTIVE

*B.S.K.Naidu, IREDA, India*

## 6.1. Introduction

Among the non-conventional sources of energy, the use of the energy potential in agricultural wastes shows good promise. India produces nearly 350 million tonnes of agricultural waste every year. The major agro wastes are bagasse, rice husk and various cereal straw.

*Major agro wastes available in India*

| Type of Agro waste | Quantity (in Million Tonnes) |
|---|---|
| Rice husk | 10.00 |
| Bagasse | 31.00 |
| Groundnut shell | 11.10 |
| Stalks | 2.00 |
| Various oil stalks | 4.50 |
| Straw of various pulses & cereals | 225.0 |
| Others | 65.90 |
| **Total** | **350.00** |

The focus of this paper is on the evolution and commercialization of the binderless briquetting technology of India so as to use these vast resources of agro-residues.

## 6.2. Process and Technologies

### Process

Briquetting is the process of densification of biomass to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel. The densification of the biomass can be achieved by any one of the following methods: (i) Pyrolysed densification using a binder, (ii) Direct densification of biomass using binders and (iii) Binderless briquetting.

### Binderless technologies and their merits/demerits

The compaction of loose biomass without any binder is done using the technologies described below. The relative merits and demerits are described briefly also.

Die and punch technology

In the die and punch technology, which is also known as ram and die technology, biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain a compacted product. The standard size of the briquette produced using this machine is 60 mm, diameter. The power required by a machine of capacity 700 kg/hr is 25 kW. The ram moves approximately 270 times per minute in this process. The main merits and demerits of this technology are :

- There is lesser relative motion between the ram and the biomass and hence, the wear of the ram is considerably less. However, wear and tear of the die is greater.
- It is the most cost-effective technology currently offered by the Indian market.
- Some operational experience has now been gained using these machines.
- The moisture content in the raw material should be less than 12% for best results using this machine.
- The quality of the briquettes goes down with an increase in production for the same power.
- Carbonisation of the outer layer is not possible. Briquettes produced are somewhat brittle.

Screw technology

In this process, the biomass is extruded continuously by one or more screws through a taper die which is heated externally to reduce the friction. Here also, due to the application of high pressures, the temperature rises fluidizing the lignin present in the biomass which acts as a binder. The outer surface of the briquettes obtained through this process is carbonized and has a hole in the centre which promotes better combustion. Standard size of the briquette is 60 mm diameter. The main merits and demerits of this technology are :

- The output from the machine is continuous and not in strokes, and is also uniform in size.
- The bulk density is higher (1500 kg/cu.m against 1200 kg/cu.m for the die & punch technology).
- The outer surface of the briquette is carbonized facilitating easy ignition and combustion and also provides an impervious layer for protection against moisture ingress.
- The central core of the briquette is hollow which provides a passage for supplying the air necessary for combustion.
- The machine runs very smoothly with no shock loads.
- The machine is very light due to the absence of reciprocating parts and flywheel.
- There is no alternate suction and pressurisation of machine thereby reducing the possibility of dust collection in the machine.
- The power consumed by this equipment is very high.
- The wear rate of the screw is very high.
- There is a limitation on the raw material that can be compacted.

Hydraulic press based technology

This process consists of first compacting the biomass in the vertical direction and then again in the horizontal direction. The standard briquette weight is 5 kg. and its dimensions and 450 mm x 160 mm x 80 mm. The power required is 37 kW for 1800 kg/h of briquetting. This technology can accept raw material with moisture content up to 22%. The process of oil hydraulics allows a speed of 7 cycles/minute (cpm) against 270 cpm for the die and punch process. The slowness of operation helps to reduce the wear rate of the parts. Further, the relative movement of the material within the die is only for a limited length. The wear and tear of the machine will be lower than those currently available machines in the Indian market. The merits/demerits of this technology are as follows :

- This technology can be used to compress any type of agro waste.
- Raw material with moisture content upto 22% can be briquetted.
- The power consumption is less compared to existing contemporary technologies.
- The output of the machine is uniform.
- The wear and tear of equipment will be less.
- The cost of the machine is high.
- The operational results are yet to be made available for Indian raw material.

## 6.3. Indian Scenario of Biomass Briquetting

### Economics

The cost of conversion to briquettes works out to Rs. 650 to 700 per tonne based on the actual field data. This high cost is due to the high wear and tear of equipment and high consumption of electricity. Apart from this, high interest on working capital and term loan is also required to be paid by the manufacturers. Typical cost of conversion of the agro-waste into briquettes is placed in Annexure 1.

Unless the cost of conversion is brought down to Rs. 300/- to Rs. 400/- per tonne, this product cannot compete with coal or lignite. Thus in states like Orissa, Bihar, West Bengal etc. which are near to the coal belt the briquetting industry is not competitive. However, in states such as Punjab, Haryana, Rajasthan, Gujarat, Karnataka, Tamil Nadu, Kerala etc., which are situated away from the coal belt, and incur high coal transportation costs the briquetting industry is competitive.

### Issues in the sector

Market

If transportation is not a problem, the industries may benefit from using the agricultural wastes directly in their boilers and in furnaces using fluidized bed combustion technology. The briquetted fuel makes biomass available in a compact form facilitating easy transportation and handling for use in almost any type of old or new burning grates. Briquetted fuel is used currently in tobacco, textile, and tea industry in addition to brick kilns.

*Problems in Marketing*

The main problems associated with marketing of the bio-coal are :

- The seasonal requirements of briquettes by the end users like brick kiln and tea industries.
- Further, the industry faces problems due to non-availability of sufficient working capital necessary to store the briquettes and sell it in periods of fuel shortage.
- There are problems associated with use of briquettes in certain types of industrial boilers.
- The availability of the raw material is seasonal requiring sufficient storage space thereby increasing the capital cost of briquetting projects.

Expertise in machine manufacturing

In India the binderless briquetting technology started as early as 1980 using the Die & Punch technology. Most of the Indian machines of this type have been designed by reverse engineering on the imported machine of Fred-Hausman. The credential of the suppliers in terms of quality of the machine and performance standards are vital factors to be considered when selecting the equipment supplier. Stress calculations of the machines also have to be evaluated while choosing the machine.

Promoters

In India, most of the manufacturers of biomass briquettes are first generation entrepreneurs. Further, most of the units are family concerns. Lack of professional management of the plant has been identified as a major drawback impeding the commercial success of this technology. It is recommended that the prospective promoters have the opportunity to increase their knowledge of the functioning of such an industry through suitable training programmes as this will reduce considerable cost and time in maintaining the project.

## 6.4. IREDA's Role in Biomass Briquetting

**General**

IREDA is the only national level institution financing biomass briquetting projects. It has been financing biomass briquetting projects involving binderless technology since its inception in 1987. IREDA has so far sanctioned 28 projects out of which 12 are in operation and 7 are under implementation. 9 projects have yet to be implemented. The largest plant financed by IREDA is in Gujarat having a capacity of 14.2 MT/year, i.e., 50,000 Metric Tonne of Coal Replacement (MTCR)/year. Nearly 1,00,000 tonnes of equivalent coal will be replaced every year by the total capacity of the plants financed by IREDA so far. The total loan amount disbursed by IREDA for these projects is Rs. 48 million.

IREDA has funded a project where the main promoters are women under a co-operative society. They have developed a 100 kg/hr machine based on the experience gained from this plant. They are planning to undertake a large scale programme envisaging the installation of portable briquetting (100 kg/hr) machines at a regional level apart from setting up a single large scale unit in Gujarat. IREDA has sanctioned term loans for 3 projects for the weaker section of the society and 3 projects to ex-servicemen. Most of the projects sanctioned by IREDA are in rural areas creating employment for rural people.

**Development and promotional role**

As some of the IREDA financed briquetting projects have faced problems like poor operation of the plant, high conversion cost, frequent break downs and poor capacity utilization a study was commissioned through the School of Energy, Bharathidasan University, Tiruchirapalli to assess the reasons for non-performance of these plants. Based on the recommendations of the study, IREDA subsequently set up a `Technical Back-up Cell' (TBC) at the School of Energy, during 1994-95 at a cost of nearly Rs. 1 million to provide technical backup support to the briquette manufacturers sponsored by IREDA.

Further, in order to gain a fuller understanding of the overall national situation, IREDA commissioned a diagnostic study on the functioning of non-IREDA assisted briquetting plants through M/s Energy, Economy & Environment Consultants, Bangalore.

**Study of IREDA funded briquetting plants by School of Energy, Tiruchirapalli**

Some of the major findings of the School of Energy after focusing their attention on the IREDA funded units are as follows:

- All the project promoters are first generation entrepreneurs and they lack the managerial experience to run an established industry such as the briquetting industry.
- Machine manufacturers have not set right many problems of their machinery. Promoters were also not in a position to rectify these on their own.
- End user's problems like loss of boiler pressure and clogging etc. adversely affect the marketability of briquettes.
- Cost of conversion of raw material to briquettes is very high.
- Research is needed to increase the production capacity, to reduce the wear and tear and increase the available time of machine.

<u>Technical Backup Cell : (TBC)</u>

Based on the study conducted on the IREDA financed briquetting plants a Technical Backup Cell was formed at the School of Energy in March, 1994 to identify the areas where modifications were required and to carry these out. The TBC has classified the issues to be studied as Technical and Operational.

*Technical issues*

In terms of the technical issues, attempts are being made to increase production, solve end user problems and design a new machine suitable for Indian raw material.

*Production*

- Increasing production by introducing restraining features on the briquetting machine like variable vertical feed rate.
- Modifying features inhibiting continuous operation.
- Enhancing the wear life of components.
- Minimizing the raw material loss during material preparation.

*Equipment*

In order to have a sustainable production level in the industry, the following areas have been identified by TBC to be studied in detail :

- Balancing of machine parts
- Reduction of power consumption
- Trouble shooting of Electrical Contactors
- To design, if possible a new machine in collaboration with reputed machine manufactures like CMTRIL for typical Indian raw materials with lesser wear and tear of parts.

*Safety and environment*

The following areas are being addressed :

- Danger of fire in drier system
- Dust pollution of the lubricated parts of the machine
- Air pollution in the shed

*End user*

Reduction in temperature and pressure in boiler which uses the briquettes, fusion and clinker formation, increased unburnts, disintegration of briquettes during combustion, quick burning of briquettes in moving grates are some of the problems reported by the end users of briquetting. These issues are also being examined by the TBC.

*Operational issues*

The operation, maintenance and monitoring of the machines are the main areas to be concentrated on. The following have been identified for studying in greater detail:

- Regular maintenance of machines.
- Replacement of the worn-out parts at regular intervals.
- Change of lubricating oil daily in small quantities.
- Monitoring of the moisture content of the raw material.
- Maintaining a sufficient number of spares to replace worn parts.

*Operational business strategy*

To help the project promoters run the unit very smoothly without any problems of raw material procurement and to reduce the cost of production the following suggestions have been given to the promoters.

- Evaluate the availability of non-competitive and cheaper options.
- Managing raw material collection and storage.
- Optimise overheads.

Based on the above, the Technical Backup Cell has done extensive trials in the following units:

- Gayathri Bio Fuels - Chellekare - Bangalore, Karnataka
- Arun fuels Ltd - Singampatti - Bhavani, Tamil Nadu
- Agri Carb Ltd. - Tirunelveli - Tamil Nadu
- Gujarat Fuel Bonanza - Lakthar - Gujarat

*Outcome of the Study of TBC*

The following is the gist of the outcome of the study conducted and trials undertaken by TBC at various IREDA funded units.

- Increase in production rate achieved by varying the vertical feed screw to vary the feed rate of raw material to the feeder box.
- Increase in production by increasing the ram length marginally.
- Exchangeable bottom of feeder box was designed to reduce the gap between ram and feeder box reducing the dust pollution.
- Additional cooler for cooling oil to increase the uptime of machines was trial tested and found to be working satisfactorily.
- Hollow chisel has been designed and fabricated to increase the production time available for machine, by reducing the time of chiselling out material in die during power failure.
- A filtration system using a recyclable ground nut shell bed has been used for reducing the dust pollution in the atmosphere.
- Test trials have been done with different materials like manganese, Nihard sterlite to reduce the wear of die and punch.
- Spark arrestor has been designed for drier system to eliminate the danger of fires.
- Disintegrator has been designed to pulverize the material instead of Hammer Mill which has also been tested.

**Study conducted by Energy, Economy and Environmental Consultants, Bangalore**

To assess the working of the non-IREDA financed Briquetting plants in the country, a diagnostic study was assigned to M/s Energy, Economy and Environmental Consultants (3EC), Bangalore. The study was conducted by 3EC on 11 briquette manufacturing units and 4 machine manufacturing units.

The major findings of the study are listed below :

- Most of the units have high equity of 70% to 100%.
- They are all of small size (10-20 T/day)
- Most of the units have only labour oriented material handling.
- All the units use only a single type of raw material.
- Very small market.
- The overheads of the companies are very low.
- Family run units.

In order to broaden the base of the briquetting industry the following suggestions have been made by the consultant.

- Reduce equity
- Increase plant size (70-100 T/day)
- Use mechanical material handling system.
- Use multiple raw materials available locally at competitive prices.
- Make efforts to keep the overheads low.
- Widen the market.
- Manage units more professionally.

To achieve the economic viability of broad based units R & D inputs are required in the following areas:

| | | |
|---|---|---|
| Operation and maintenance | - | Problems of wear and tear and lubrication. |
| Mechanical handling system | - | To be mechanised from the yard to the loading point. |
| Biomass character | - | The problems associated with improper combustion, clinker formation, ash deposition and wear caused by a particular raw material. |

**IREDA's approach towards the biomass briquetting sector**

Based on the expert studies conducted by the School of Energy and Energy, Economy & Environmental Consultants, and on its own experience, IREDA proposes to continue to support this sector. It would, however, prefer to concentrate on equipment financing and would expect the entrepreneurs to supply all other project requirements. Emphasis would be given to the tail end units at the rice mills, sugar mills, pulp and paper industry, oil mills, coffee and tea gardens etc. Where raw material supply is assured, marketing linkage would of course be a prerequisite. Agro-waste based rural units would continue to be supported. In order to boost the large scale commercialization of the technology more fiscal incentives are desirable. The proposed and available incentives are given at Annexure 2 which reveal the scope for improving upon the overall policy support to this sector.

## 6.5. Concluding Remarks

The agricultural wastes available in India are virtually unlimited. If technology can be perfected, organisational and policy support strengthened, institutional financing continued, training and professional inputs backed up; biomass briquetting can make a modest beginning in the recycling of agro-waste for energy recovery which is a need of the day for environmentally sustainable development.

## 6.6. References


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- ! A Diagnostic study on Non-IREDA financed briquetting projects - Energy, Economy & Environmental Consultants, Bangalore, 1994.


## 6.7. Annexes

**Annexure 1: Cost of Conversion**

| | | |
|---|---|---|
| Installed capacity | : | 1.25 MT/year |
| Total raw material cost including transport | : | Rs. 450/ton |
| Total consumable's cost | : | Rs. 10/ton |
| Power cost | : | Rs. 80/ton |
| Repair and maintenance | : | Rs. 70/ton |
| Selling expenses | : | Rs. 100/ton |
| Salary and wages | : | Rs. 65/ton |
| Interest and repayment | : | Rs. 150/ton |
| Total cost of conversion | : | Rs. 935/ton |
| Total sales price | : | Rs. 1300/ton |
| Total profit | : | Rs. 365/ton |

Two machines are proposed since either of the machine will be in operation. In addition the spares management and administrative and selling expenses will be reduced.

**Annexure 2: Incentives for Briquetting Sector Projects and Eequipment**

| | INCENTIVES -> | Existing | Proposed |
|---|---|---|---|
| | **CENTRAL GOVT. INCENTIVES** | | |
| 1 | Accelerated Depreciation<br>(100% in the Ist year) | Yes | Yes |
| 2 | Income Tax Holiday for Power/Energy Generation<br>(First 5 year - Nil)<br>(Next 5 year - 70%) | N.A. | Yes |
| 3 | Concessional Customs Duty | 40% | 10% |
| 4 | Auxiliary Duty | Nil | Nil |
| 5 | Excise Duty | Nil | Nil |
| 6 | Central Sales Tax | * | Nil |
| 7 | Priority Sector Status (For priority lending) | N.A | Yes |
| | **STATE GOVT. INCENTIVES** | | |
| 1 | Sales Tax Concession | Nil | Yes |
| 2 | Sales Tax Benefit (Deferment/exempn/transfer) | N.A | Yes |
| 3 | Octroi | * | Nil |
| 4 | Capital Subsidy | Yes | Yes |

N.A. - Not available * - Information available

# 7. SOME ASPECTS OF SCREW PRESS BRIQUETTING

*S.C.Bhattacharya, S.Jungtiynont, P.Santibuppakul and V.M. Singamsetti, Bangkok*

## 7.1. Introduction

Densification has aroused a great deal of interest in recent years for the beneficiation of agricultural and forestry residues as energy source. Basically, densification techniques can be classified into two broad categories based on the operating conditions: hot and high pressure densification or cold and low pressure densification (Bhattacharya et al., 1989). Depending on the type of equipment used, hot and high pressure densification can be categorized into four main types: piston press densification, screw press densification, roll press densification and pelletizing. Products from the first three types of densification are of relatively large size and normally called briquettes. This paper presents a summary of heated die screw press briquetting studies carried out at the Asian Institute of Technology, and reviews the status of the technology in Thailand.

## 7.2. Screw Press Briquetting Technology

Three types of screw presses have been used for briquetting : conical screw press, screw press with heated die, and twin screw press.

### Conical Screw Press

The raw material is compressed by a conical screw. The screw forces the material into the compression chamber. A rotating die head extrudes the material through a perforated matrix to produce briquettes of diameter about 2.5 cm. A knife cuts the densified product to a specified length. The conical screw press can also be used to produce briquettes with diameters of about 10 cm by using a single-die matrix.

### Screw Press with Heated Die

The material is forced by a screw, having no taper or a small taper, through a die heated, usually electrically, from outside. The die has a number of ridges which serve to prevent the densified material from rotating with the screw. The briquettes are 5-10 cm in diameter. The die temperature is normally maintained at about 300 $^0$C. The raw material gets heated up to about 200 $^0$C during the process, most of the heating being caused by friction. The briquettes often get partially pyrolyzed at the surface, which causes quite a lot of smoking during briquetting. The design of the screw results in the formation of a central circular hole in the briquette; this acts as an escape route for steam formed during briquetting.

### Twin Screw Press

In a twin screw two adjacent gripping shafts fitted with screw parts with varying leads, rotate closely and opposed to each other in "8" shaped casings. These casings are constructed as pressure casing boxes with cooling or heating section, as well as partly open sections with steam exhausts. Due to high pressure and friction, the temperature of the raw material could rise up to 25 $^0$C. The steam produced during densification is extracted by steam removal units. The briquette is extruded axially. In this press raw material having a particle size 30-80 mm and moisture content upto 25% can be densified without predrying. Throughput capacity of the press varies from 2800 -3600 kg/hr depending on the raw material composition (Schraufstetter, 1988).

## 7.3. Heated Die Screw Press Briquetting

### Wear and Maintenance

The major maintenance problems of the heated-die screw press briquetting machines are due to the high wear rate of the screw and the die. Normally a screw requires repairing after every 100 hours of operation and needs replacement after every three repairs. The die needs replacement after every 1,000 hrs of operation. The wear of the die and the screw results in a significant operating cost and calls for the regular attention of the plant owner (Bhattacharya et al., 1990). It appears that the problem of high wear can be solved by preheating the raw material to be briquetted. Preheating results in a lower densification pressure requirement and is expected to reduce wear.

### Manufacturers

Table 1 shows the number of heated die screw press briquetting machine manufacturers in various countries as identified by a survey carried out in 1988 (Bhattacharya et al., 1990).

*Table 1: Number of heated die screw press briquetting machine manufacturers by country surveyed.*

| Country | Austria | Chinese Taipei | Fin-land | Germany | Ire-land | Japan | Switzer-land | Thai-land | USA |
|---|---|---|---|---|---|---|---|---|---|
| No. of manufacturers | 1 | 3 | 1 | 1 | 1 | 4 | 1 | 3 | 4 |

### Design Variations

An Austrian manufacturer (Pini and Kay, Vienna) appears to have developed a heated-die screw press that employs a two-piece screw. It has been reported that the average service life of the screw surpasses 500-800 hours (Kubinsky,1986) and the worn screw can be reconditioned at a relatively low cost. Adoption of this technology could enhance the viability of briquetting by ensuring relatively "maintenance-free" operation. Briquetting machines are normally of the single extrusion type. Multiple-die machines, which are less common, are capable of 2 or 3 extrusions simultaneously. The capacity of the machines ranges from 50-500 kg/hr (Carre et al., 1987).

### Energy Required for Briquetting

Carre et al.(1987) studied the energy consumption of different types of briquetting machines using different raw materials. They found that for the heated die cylindrical screw press, the actual energy consumption was 100-200 kWh/ton for wood materials, 110-170 kWh/ton for agro-industrial residues and 150-220 kWh/ton for agricultural residues. Reed et al. (1980) found that the work and pressure of compression or extrusion can be reduced by a factor of about two by preheating the raw material.  This result was not unexpected since it is normally accepted that lignin, a constituent of biomass, becomes soft at the temperatures encountered in densification and acts as an internal glue.  In conventional briquetting, the biomass is heated by friction as it is forced through the press by the screw.  If the raw material is heated outside of the briquetting machine, the lignin will already be soft when it is fed to the press and less force and energy are required to compact it.

Aqa and Bhattacharya (1992) studied the effect of varying the die temperature and the raw material (saw dust) preheat temperature on the energy consumption for sawdust densification using a heated-die screw press.  A significant amount of energy could be saved by densifying sawdust preheated to a suitable temperature.  The energy inputs to the briquetting machine motor, die heaters and the overall system were reduced by 54, 30.6 and 40.2%, respectively in case of sawdust preheated to 115 $^0$C. The decrease in the electrical energy requirement per kg of sawdust allows operation of the briquetting machine at higher throughput with the existing motor.  Operating the briquetting machine at higher throughput further reduces the electrical energy requirement per kg of sawdust.

## 7.4. Carbonization and Torrefaction of Briquettes

### Carbonization

Charcoal is a premium fuel widely used in many developing countries to meet household as well as a variety of other needs.  It is however often difficult, if not impossible, to find a sufficient supply of firewood for charcoal making.  Substitution of wood charcoal by biocoal, which is charcoal obtained from agricultural and forestry residues, appears to be an attractive option to alleviate the traditional fuel crisis faced by many developing countries.

Biomass briquettes can be carbonized to produce charcoal briquettes.  The carbonization process can be carried out in kilns similar to conventional brick and metal kilns used for making charcoal from wood. In a test run of an industrial plant in Thailand, the yield of charcoal from sawdust briquettes on ash-and moisture-free basis was found to be about 35%.  In a study carried out at the Asian Institute of Technology (Bhattacharya and Bhattacharya, 1989) using a 2 cubic meter brick kiln, the yield was found to be in the range of 33.5 to 41.3%.

### Torrefaction

Charcoal making is a rather inefficient process, with the product containing only about 55% of the energy of the original raw material in well-managed, commercial operations and as little as 20% in traditional processes.  Low temperature carbonization of biomass to obtain roasted or "torrefied" products is a relatively recent development.  During the process wood has been reported to lose only 7 to 10% of its energy content while losing upto 30% of its weight.  Torrefied products can substitute charcoal in a number of applications (Bourgeois and Doat, 1985). A study by Pentananunt et al. (1990) showed the weight and energy yields of torrefied wood to be 66.7-83% and 76.5-89.6%, respectively. The corresponding values for sawdust briquettes were 76.3-93.8 and 83.1-95.3%, respectively. Torrefied briquettes have superior combustion characteristics as compared with ordinary briquettes.  Thus, combustion tests showed that the torrefied briquettes, particularly of rice husk, were easier to ignite and burned much faster with less smoke compared with ordinary briquettes.

The technique of low temperature carbonization appears to be particularly attractive for upgrading briquettes since the resulting torrefied briquettes show better combustion quality and improvement in water resistance.  Also since the briquettes emerge from the briqetting machine at high temperature, only a small amount of additional energy input would be necessary for producing torrefied briquettes.

## 7.5. Status of Briquetting in Thailand

In the late 1970s, a private entrepreneur introduced screw press briquetting into Thailand by importing a set of 4 briquetting machines from Taiwan.  In 1982, he started production of briquetted charcoal by carbonizing sawdust.

### Manufacturers

In late 1980s there were three heated die screw press briquetting machine manufacturers in Thailand.  At present, there are five.  However, only one out of these appears to have sold a significant number (>200) of machines.  At present, there is not much demand for briquetting machines; the manufacturers therefore normally produce briquetting machines only on order.

### Uncarbonized Briquettes

! The market for uncarbonized briquettes is limited.  A survey carried out in late 1980s found that the briquettes were mainly used as cooking fuel by Cambodian refugees who got a fixed amount of briquettes free of cost.  Small amounts of briquettes were also used in temples for cremation.  Except in the refugee camps, direct use of briquettes was not attractive for household users since existing charcoal stoves do not burn the briquettes efficiently resulting in the generation of smoke.

! A number of briquetting plants that were installed in the early 1980s were not operating by the late 1980s.  In 1989 there were only 2 rice husk briquetting plants and 7 sawdust briquetting plants.

! The production of sawdust briquettes appears to have steadily increased during 1980-1995, while the production of rice husk briquettes has declined.

! Currently, there is only one more sawdust briquette producer than there was in 1989.

**Carbonized Briquettes/biocoal**

- ! In 1989 there were three biocoal plants producing biocoal from sawdust.

- ! The production of biocoal in all factories was aimed at export since export prices were much higher than domestic prices. Only the surplus left after export and biocoal below export quality was sold in the domestic markets.

- ! Biocoal is mostly used by food vendors who sell food from mobile stalls. The quantities of fuel bought by them each time are relatively small and just enough to meet the daily requirement. This makes biocoal cheaper than wood charcoal.

- ! The attributes of biocoal that most users like include its non-sparking characteristic, low smoke generation, low ash content, economy in use and long lasting fire. An attribute of biocoal that some users do not like is the difficulty in starting the fire, apparently because of low porosity.

**Economics**

The economic aspects of briquetting are presented in Table 2 for a plant with four briquetting machines each having an average capacity of 120 kg/hr with one set of drying equipment and other auxiliaries. It is assumed to run in one 8 hour shift per day and produce sawdust briquettes. Sawdust from the storage hopper, located above each machine, is fed by gravity to the screw inlet and briquetted sawdust comes out through the die outlet. Each machine is attended by one worker for proper feeding, removal, and storing of briquettes. Although the table is from a study (by Bhattacharya et al., 1990) published about five years ago, the results shown can still be regarded as roughly indicative of the current cost of briquetting.

*Table 2. Briquette production cost at a raw material price of 300 and 474 Baht/ton*

| Items | Baht | |
|---|---|---|
| | Raw material Price = 300 Baht/ton | Raw material Price = 474 Baht/ton |
| Fixed Costs: | | |
| Equipment | 700,000 | 700,000 |
| Building | 578,800 | 578,800 |
| Total | 1,278,800 | 1,278,800 |
| *Annual Component of Fixed Cost | 187,984 | 187,984 |
| Annual Expenses | | |
| Labour | 289,000 | 289,000 |
| Electricity | 250,700 | 250,700 |
| Raw material | 519,300 | 820,500 |
| Drying | 79,200 | 79,200 |
| Maintenance cost | 120,400 | 120,400 |
| Land rent | 60,000 | 60,000 |
| Total | 1,318,600 | 1,619,800 |
| Total Annual Cost of Briquette Production | 1,506,583 | 1,807,783 |
| Total Annual Briquette Production | 1,248 | 1,248 |
| Ex-works Production Cost of Briquettes : Baht/ton | 1,207.198 | 1,448.545 |
| Baht/kg | 1.207 | 1.449 |

* Capital Recovery Factor for 15 years life and 12% interest rate is 0.147
Currency conversion rate : 1 US$ = 25 Baht (approx.)
Source : Bhattacharya et al. (1990)

## 7.6. Concluding Remarks

Screw press briquetting is an established technology for upgrading biomass of low bulk density as an energy source. In the developing countries, briquetted biomass is normally not a commercially viable substitute for fuelwood. One successful commercial application of heated die screw press briquetting is production of briquetted charcoal (by carbonization of sawdust briquettes) for the international market.

Preheating biomass is an interesting option for reducing energy consumption, to reduce wear of machine parts (due to lower densification pressure requirement) as well as production cost (due to reduced energy and maintenance costs). Torrefaction appears to be suitable technique for improving the fuel quality of briquettes. Only a small amount of additional thermal energy input should be necessary for torrefying the hot briquettes emerging from the machines.

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# 8. BIOMASS DENSIFICATION IN INDONESIA

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## 8.1. Introduction

The share of biomass in the country's energy supply system, estimated to be in the order of around 35%, is substantial. In line with the country's energy diversification program, which aims at a declining share of oil in the domestic supply mix, increased use of alternative energy sources, including biomass, has been pursued. Interest in developing biomass energy is also encouraged by the growing concerns over the adverse environmental effects of fossil fuel utilization.

Regarding energy technology, R & D work in the field of biomass preparation technology including biomass densification has been very limited in Indonesia. This paper presents an overview on the status of biomass densification in the country. The discourse will be mainly concerned with information gathered from activities over the past decade, however the future direction of biomass densification development will also be briefly discussed.

## 8.2. Resources and Uses of Biomass

Table 1 presents agricultural acreage and biomass residue production of Indonesia in 1989.

*Table 1. Agricultural acreage and biomass residue production of Indonesia in 1989 [1].*

| Type of residue | Acreage (million ha) | Residues (million tons) |
|---|---|---|
| Rice residues | 10.5 | 59.0 |
| Corn cob | 2.9 | 3.3 |
| Peanut shell | 0.6 | 0.3 |
| Soybean stalk | 1.2 | 2.1 |
| Cassava | 1.2 | 6.7 |
| Cane bagasse | 0.4 | 8.5 |
| Coconut residue | 3.3 | 5.4 |
| Palm oil residue | 1.0 | 6.2 |
| Rubber wood residue | 3.0 | 57.0 |
| Coffee plantation residue | 1.0 | 3.5 |
| Logging residue | 30.0 | 8.5 |
| Wood processing residue | - | 11.4 |

As can be seen in Table 1, the rice sector is the largest producer of biomass residue. Rice is the most important commodity of the country's agricultural sector. Basically, rice the sector generates three types of biomass residues, namely rice straw, rice husks and rice bran. Only a small amount of rice straw is used in paper making while the rest is returned to the field as soil nutrient or burnt at the field. A small part of the total amount of rice straw is utilized to produce traditional household utensils/handicrafts. Rice straw is reported to be used also as a medium for mushroom cultivation. Rice bran, given its nutritional value, is usually sold as cattle and/or poultry feed. At present rice husk is generally of little practical use and economic value. Husks are usually burnt at the rice mills or used to supplement firewood in households or small industries (brick making etc.).

Bagasse is the most important by-product of the sugar industry. The primary use of bagasse is as the main fuel for the production of steam and electricity in the sugar mills. Over 90 percent of bagasse now produced in sugar mills is used for this purpose. Most of the mills are self-sufficient in energy and many of them are still left with a large amount of excess bagasse. Some of this surplus is usually reserved for power production during off season or at the beginning of the next season. At some sugar mills a small portion of the excess bagasse is sold as a pulping feedstock for paper and board.

Other biomass wastes of the sugar sector are leaves and cane tops. They represent as much as 30 percent of the total biomass in cane fields before harvest. Smallholders, mainly in Java, use a small amount of this material for animal feed, while large estates generally leave it on the ground at harvest. This material could provide a substantial additional source of biomass for the cane industries. Residues from palm oil mills include palm kernel, fiber and empty fruit bunches. Except for the bunches, all biomass residues of palm oil mills are utilized to fuel the mills. The bunches are usually burnt in an incinerator to obtain bunch ash to be used as the palm fertilizer.

Severe competition has emerged for the export of rubber wood logs with diameters over 10 cm which in the past were considered a waste product and were usually used as firewood or just burnt in the plantation. Considering this trend it can be expected that the availability of rubber-wood logs with a diameter greater than 10 cm will be soon limited, principally due to the demand generated by the timber industry. The only rubber residue will be the small branches and twigs. So far only a minor fraction is used by estate workers and villagers as fire wood, but most residues are simply burned in the field.

Biomass residue of the coconut sector consists of coconut husk (fiber) and coconut shell. Dried coconut shells and husks are usually used by rural households to supplement firewood in cooking. The coconut shells are also processed into charcoal. This type of charcoal is popular among charcoal users as it produces less smoke and stands longer (higher energy density) than wood charcoal. Coconut charcoal is also consumed by manufacturers of mosquito coils. Recently, there has been an emerging interest in the production of coconut shell charcoal as a result of the increasing demand for its use in the production of activated carbon.

The forest sector generates logging residues and wood industry (plywood, sawmill, furniture etc.) residues. Medium and large sawmills utilize milling residue to fuel boilers for timber drying. In some cases, sawmills also use milling residue to generate power for the milling operations. Some industries are also reported to be processing sawmill residues for activated carbon and charcoal. The majority of sawmill residues are either burned in piles or disposed of into nearby rivers.

## 8.3. Biomass Densification Technology

In Indonesia where the price of conventional fuels is relatively cheap and firewood is abundantly available, densified biomass, particularly the uncarbonized type, is not a popular fuel. The only user of densified biomass in the country is some households in big cities which sometimes use a limited amount of smokeless charcoal briquettes as bar-be-que fuel. These briquettes are usually imported products and sold in supermarkets in big cities. As compared to efforts in the development of biomass conversion technologies, R & D work in the development of densified biomass is relatively rare. Some experimental work in the development of charcoal briquettes has been undertaken by some research agencies. The raw material for these briquettes includes wood, sawdust, rice husk pyrolysis char, coconut trunk, coconut shell and peat [2,3,4,5,6]. In these experiments, manually operated press machines or granulators have been used. Various shapes of briquettes have been developed and include cylindrical, cubes and balls. The binding agent usually used is starch solution. Other binders such as molasses, cement and asphalt have also been investigated.

There are a limited number of export-oriented charcoal briquette producers in the country. The raw material of the briquettes is usually coconut shell and sawdust. One of these producers has a production capacity of around 2400 ton per year. The export markets are usually Europe and Japan. Besides exporting, these producers also sell the product in local markets, primarily in supermarkets of big cities.

## 8.4. Prospects for Biomass Densification

Considering the availability of abundant biomass resources and the fact that the number of domestic competitors is still limited, the prospects for the densified biomass industry in Indonesia, particularly those which are export-oriented, seems to be good. Development of uncarbonized biomass densification for domestic uses using cheap biomass such as rice husk, may be justified when appropriate devices for the utilization of the densified biomass (stoves or industrial burners) are developed or made available in the country and the price of the product is competitive with conventional fuel.

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# 9. BIOMASS BRIQUETTING IN THE PHILIPPINES

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## 9.1. Introduction

The Philippines has an abundant supply of biomass resources in the form of agricultural crop residues, forest residues, animal wastes, agro-industrial wastes and aquatic biomass. Some of these resources are already being exploited. In 1994, bagasse and other agriwaste (woodwaste, coconut shell/husk, etc) accounted for 3.5% and 5.6% respectively, of the national energy mix and the contribution is projected to rise modestly. This contribution is mostly due to large industries and does not include the use of fuelwood by households and other small enterprises.

Nevertheless, there still remains an untapped supply of bagasse, ricehusk and coconut husk, among others, due in part to: (a) inefficient use of resource, such as bagasse in the sugar industry, (b) dispersed location of resources, (c) low bulk density of biomass resource, (d) limited economic uses whether for energy of non-energy purposes and (e) lack of or insufficient knowledge on the alternative use of these resources.

The Philippine Department of Energy is currently promoting the development and widespread use of biomass resources, especially, bagasse, rice husk and other agriwastes, by way of encouraging pilot-testing, demonstration and commercial use of biomass combustion systems, gasification and other systems for power, steam and heat generation.

In 1990, the then Office of Energy (now Department of Energy) conducted the "Biomass Densification Research Project in the Philippines" for the Unviersity of Twente and the Dutch Ministry of Development Cooperation. The project investigated the status and extent of biomass briquetting in the country. Based on the project's findings, there is limited commercial production of biomass briquettes in the country. In view of the abundant supply of raw materials, there is a large potential for biomass briquetting, particularly for the export market. Furthermore, the technology presents an opportunity to dispose of unwanted waste and at the same time provide an alternative livelihood to some communities. As such, there is a need to conduct promotional and commercialization activities to further promote biomass briquetting in the Philippines.

## 9.2. Biomass Resources in the Philippines

The Philippines has an abundant supply of biomass resources such as agricultural crop residues, forest residues, animal wastes, agro-industrial wastes and aquatic biomass, among others. Based on the UNDP-World Bank ESMAP estimate, as of 1989, the Philippines has 3,500 million tons wood equivalent (8,960 million barrels of fuel equivalent) of standing stock, with an annual sustainable yield of 105 million TWE (270 MMBFOE). The estimated annual use of biomass us 35.66 million TWE or 91.28 MMBFOE.

The most common agricultural wastes are rice hull/husk, bagasse and coconut shell/husk. Woodwaste/wood fuel is also extensively used and can be obtained from the forest and other resources.

### Rice Husk

Rice husk (hulls or chaff) is a by-product of rice milling. It is the tough covering which surrounds and protects the rice kernel. It accounts for 20% of the rice paddy, as estimated by the National Food Administration (NFA). In 1991, rice hull production was a considerable 1.9 million metric tons. However, rice hulls are available only from rubber roll and cono ricemills where the hulls are separated from the rice bran. NFA estimates that the available rice hull for fuel is only 5,156 tons per hour.

In certain parts of the Philippines, rice hulls are used as fuel in households and rural industries. Special stoves using rice hulls have been designed and are sold in some parts of the country. Some old rice mills use rice hulls to generate steam and electricity for in-plant use. Rice hulls are also common fuel for paddy drying and brick making. Non-fuel uses include their use as raw material for the manufacture of particle board, as livestock feed (along with rice bran), as mulching material in farms, and as insulating material, especially in rural rice plants.

### Bagasse

In the Philippines, bagasse accounts for about 87% of the total fuel mix by the sugar industry, or 851 million liters  oil equivalent (MLOE). Supplementary energy sources have been resorted to, especially by mills with auxiliary processing plants (refinery, distillery) where the bagasse produced is not sufficient to sustain the additional steam and power requirements. Because of the restrictions imposed by the present sharing system, the Philippines sugar industry finds little use for bagasse other than as fuel. There have been shortlived ventures, all thriving on the factory share of the excess bagasse, including the production of particle boards, activated carbon and hydrolyzed pith.

There are 39 operating sugar mills in the country which process about 19 million tons of sugarcane per year. Based on the study carried out by the UNDP/World Bank ESMAP/DOE Pre-Investment Study, there is excess bagasse due to inefficient and old boilers and generators. Should these equipment be replaced, additional electricity and steam can be generated.

### Sugarcane Field Trash

It is estimated that from 11 to 21 tonnes of trash are produced from one hectare of sugarcane depending on the variety and the quality of growth. The use of cane trash as an energy source is gaining ground especially in countries which do not have rich petroleum reserves.

The moisture content of this trash is comparatively lower than bagasse and its estimated higher heating value is about 4,000 kcal/kg (dry basis) making it a valuable fuel. However, one obstacle to its use is the difficulty of collection from the field. Aside from being a major fuel, a certain amount of field trash can also be used along with bagasse, filter cake and rice straw as substrate for growing mushroooms and for composting to produce organic fertilizer.

### Coconut Residues

Biomass waste in the coconut industry consists of coconut shell, husk and fronds. Coconut fronds are not normally cut, hence cannot be a reliable source of fuel. On the other hand, coconut shell and husk are reportedly accumulated in the plantation sites, at a central de-husking site, at the copra drying site, and at the coco-processing plant site. In general, the bulk of the resources, both husk and cocoshell, are amassed near the copra drying site.

Cocoshells and cocohusk are largely utilized as domestic and industrial fuel. Households usually convert cocoshell into charcoal for cooking, ironing and water heating. Cocoshells are mainly used by the desiccator facilities. A recent survey indicated that national consumption of cocoshell charcoal is about 520,000 tons per year and the consumption of raw cocoshells is about 139,000 tons per year. On the other hand, cocohusk is used as fuel by the copra drying facilities and, to a lesser extent, by households in rural areas for cooking. The national consumption of cocohusk is estimated to be about 450,000 tons per year. This residue is not traded and is viewed as a free commodity. The non-fuel uses of cocoshell include ornamental purposes, grinding agent, cocoshell flour, charcoal, activated carbon, source of coir.

### Wood/Woodfuel

Wood is an important fuel in the country. Estimates made under the UNDP/WBESMAP/DOE Household Energy Consumption Study show that woodfuel accounts for 28 million tons (82%) of a total annual consumption of 34 million tons of all kinds of wood, thus it is the dominant end use of wood raw material. Fuelwood is widely used by the households, commercial and industrial establishments, food servicing enterprises, food processing industries such as those smoking and drying fish, and in agricultural activities such as drying crops like tobacco. Numerous studies suggest that, urban centers like Metro Manila are heavy users of fuelwood. In the rural areas, fuelwood is used for cooking by 85% of households. The heavy dependence of non-conventional sources like fuelwood may be attributed to the increase in prices of oil and petroleum based fuels. Compared to the latter, fuelwood is cheaper, locally available, easy to store and transport, and simple and convenient to use.

A biomass survey using satellite imagery and field visits showed that there is an overall surplus of woody biomass of about 44 million tons, but that seasonal shortages do exist in some local areas.

## 9.3. Status of Biomass Briquetting in the Philippines

In 1990, the then Office of Energy (now Department of Energy) conducted the "Biomass Densification Research Project in the Philippines" for the University of Twente and the Dutch Ministry of Development Cooperation. The project investigated the status of biomass briquetting in the country.

**Supply of Briquettes**

The study showed nine commercial producers of biomass briquettes in the Philippines with a production capacity ranging from 1 ton per day to 50 tons per day. Four pilot briquetting plants were also found, while two rice husk briquetting plants were found to have stopped operation. In 1993, a new plant was installed in Iloilo which produces 1,000 carbonized ricehull briquettes per day.

The briquettes produced are mostly made of sawdust, charcoal fines and/or ricehusk. These are of various sizes and shapes depending on the process of operation. Briquettes are also found to be more expensive than fuelwood or charcoal. Fuelwood usually costs about P 1.00 per kg., while charcoal costs from P 2.00 to P 12.00 per kg. On the other hand, biomass briquettes are priced at about P 20 per kg.

**Present Uses of Briquettes**

The local market for biomass briquettes includes industrial users most of which are processing plants that have boilers. Briquettes sold in supermarkets are usually used for household purposes like barbecuing and roasting. It is reported that the volume of supply of biomass briquettes nationawide is still very small. Apparently, there is a low demand for the product due to: (a) low level of awareness about the product and (b) lower price and abundant supply of fuelwood and charcoal.

**Status of Production**

There are only a few manufacturers of briquetting machines in the Philippines. Research institutions like the Forest Product Research and Development Institute (FPRDI) and DOST Industrial Technology Development Institute (ITDI) have developed prototypes of briquetting machines.

**Potential Market for Briquettes**

The potential markets for biomass briquettes include the following:

- households (boiling, ironing clothes)
- small business establishments involved in food preparation and processing such as restaurants, bakeries, makers of sweets and delicacies.
- large industries that have boilers and furnaces (involved in brickmaking, porcelain glazing, lumber drying, etc).
- establishments for post-harvest processing (drying palay, tobacco, coffee beans, fruits, fish)
- export

However, as long as fuelwood and wood charcoal can easily and cheaply be obtained, households and other potential users may not be attracted to use biomass briquettes. Hence, the price of biomass briquettes has to be made competitive with the price of fuelwood, charcoal or even LPG and kerosene. The substitution of fuelwood and/or charcoal used by the above sectors with biomass briquettes presents an opportunity to use resources considered as waste, and an alternate livelihood for communities with abundant biomass resource like rice husk.

## 9.4. Strategies to Promote Biomass Briquetting

The Department of Energy through its Non-Conventional Energy Division is mandated to formulate and direct a comprehensive national Non-conventional Energy Program which seeks to develop and strongly promote the use of non-conventional energy systems and sources which are technically feasible, socially desirable and economically viable. Other agencies are also involved in the implementation of programs and projects to further develop the use of indigenous energy sources, such as biomass briquettes. These agencies include the various agencies under the Department of Science and Technology, and the Philippine National Oil Company - Energy Research and Development Center.

In view of the energy potential and positive environmental impact of biomass briquetting, the DOE considers it as one of the priority technologies for dissemination. To promote the production and use of biomass briquettes, the following activities will be or are being undertaken:

**Promotion of biomass briquettes**

At present, the volume of supply of biomass briquettes is still very small, despite the abundance of raw materials. Hence, there is a need to expand the market by promoting the fuel to potential users. However, there is a need to lower the selling price of biomass briquettes to make them competitive with available fuels in the market.

**Promotion of biomass briquetting technology**

Appropriate technologies available in the Philippines and in other countries can be disseminated through the conduct of seminars and workshops, publication of brochures and promotional materials, and other activities. The information would be of interest to local entrepreneurs and investors.

**Local fabrication of briquetting machines**

The production of briquetted biomass fuels can be achieved through small and decentralized production facilities located near the source of biomass. Thus, there is a need for locally fabricated machines including experts or technicians to install, maintain and repair the units.

**Financing for potential producers**

Financial assistance programs and other forms of fiscal incentives to support manufacturers of briquetting machines and producers of briquettes will help reduce the risks to entrepreneurs to venture into business activities in this area. The PNOC - Energy Research and Development Center is currently implementing the "Decentralized Energy Systems Project" which provides soft loans to entrepreneurs who want to commercially manufature non-conventional energy equipment like biomass briquetting machines. Fiscal incentive policies such as tax exemptions, tax credits, franchising, and others can also motivate would-be investors and producers to venture into briquette production

**Demonstration/pilot testing of emerging technologies on biomass briquetting**

New or adaptations of technologies should be demonstrated under local conditions to prove their technical, financial and economic viability, and user acceptance. Interested users are usually hesitant to invest in technologies which are new and untried for local applications.

# 10. POTENTIAL OF BIOMASS BRIQUETTING IN SRI LANKA

*T.B. Adhikarinayake, Sri Lanka*

## 10.1. Introduction

Sri Lanka, like many other countries in the region, has an agricultural economy. Non commercial energy sources consisting of fuel wood, agro waste residues and animal waste and other ligno cellulosic matter are the major sources of energy in the country representing 5.0 million tons of oil equivalent (mtoe) or 68 per cent of the energy supply (7.7 million toe in the country) in the year 1993. The balance was provided by imported petroleum products and indigenous hydro power which required heavy capital investment. The traditional sector which relies heavily on fuel wood and other biomass sources of energy, is faced with the rapid depletion of forest resources resulting from their excessive exploitation for fuel and timber and from the clearing of forests for village expansion works and agricultural activities. At the present rate of deforestation, there will soon be a severe shortage of fuelwood, and it is necessary to introduce other sources of cheap and available fuels.

## 10.2. Fuel Wood Demand

When considering the total energy supply of the country, the major share is occupied by fuelwood (about 72%) compared to imported fossil oil (17.2%) and electricity (10.7%). According to the data available, the tea industry is the largest fuelwood consumer in the country and it is estimated to consume 33%. The second largest fuelwood consumer is the hotel and eating houses sector which consumes 15%. Although in some places, LP gas and kerosene are used for convenient operation at high cost, the major portion of energy is supplied by fuel wood. Similarly, brick and tile manufacturers and coconut oil producers also consume fuelwood in almost equal quantities.

## 10.3. Availability of Agricultural Wastes

Agriculture is the principle source of income and employment for most of the rural population in the country. Increased agricultural productivity is associated with increased biomass supplies which can be converted into high grade energy sources with modern technology. Such conversion is obviously preferable from an economical and environmental perspective compared to other energy delivery systems such as imported fossil fuels. In Sri Lanka as elsewhere in the world, agricultural residues are the most abundant type of waste material available in the country. The principle agricultural residues produced in this sector are rice husk and straw, residues from tea and rubber plantations, bagasse, tobacco stem, cinnamon stick, cashew nut shells, citronella grass, cocoa shell, saw dust and animal residues.

**Paddy husk:**

Paddy is the most extensively cultivated agricultural crop in Sri Lanka. There are approximately 800,000 ha of gravity irrigated rice fields and about 500,000 ha of land cultivated with rain fed waters. Paddy is cultivated in two seasons which correspond to the two rainy seasons. The annual paddy production in 1989 was about 2.56 million tons and assuming 18-22% of husk content in paddy, about 0.35 million tons of husk is produced annually as a by-product of the rice milling industry. Disposal of this by-product has become a great problem due to its limited use. In some mills located in northern and north central parts of the country, husk is used as a source of fuel for their parboiling and drying operations. Since husk has low combustion efficiency and high ash content, it is burnt on an inclined grate made of fire bars or by blowing husk to the fire. Husk produced by stell huller type rice mills is used at household level for cooking purposes. The remainder of the husk is burnt in open space.

**Rice straw:**

Rice straw is an agricultural residue associated with paddy production and it is a lesser important source of energy. Straw is mainly used for the paper industry and also as an animal food. Some farmers use straw to cover their house roofs each harvest season. The remainder of the straw is burnt in the paddy fields to destroy weeds and to replenish the soil with potash. However, most of the nutrients and the humus are lost in this process.

**Coconut residues:**

Sri Lanka has about 420,000 ha of coconut lands and the average annual production is about 2000 million nuts. The principal wastes produced from this industry are husk, shell and coir dust. The fibre industry uses about one third of the coconut husk available. Coir dust obtained after extracting fibre is the main by-product which has very limited usage as it has a high moisture content. Recently, a few industries have initiated briquetting of coir dust as a water absorbent for the export market.

**Residues from tea plantations:**

Agricultural residues from the tea industry are those such as twigs, small branches and leaves obtained during pruning of tea bushes once every 3-4 years. A large portion of these residues is collected by the labourers and villagers for use as fuelwood for cooking. Most of the factories use firewood as a source of energy in the withering and drying processes of tea and very seldom these residues are used as a supplement for their energy requirement.

**Bagasse and tobacco residues:**

Bagasse is the portion of the sugarcane that remains after extracting juice. It contains the outer fibrous part and the inner portion containing the softer pith. Sri Lanka has two large sugar factories and they are associated with sugarcane plantations producing 300,000 tons annually giving 80,000 tons of bagasse. In addition to this the private plantations also produce about 20,000 tons of bagasse annually. Most of the bagasse produced is used in raising steam in the factories and private growers use it too for boiling and concentration of cane syrup. It is estimated that about 12,000 tons of tobacco stems are available annually as a source of energy. Most of the tobacco growing is done by small scale cultivators in decentralized plots. The processing and curing is carried out centrally by those who purchase the green leaves and it is these who have access to the stems.

## 10.4. Potential of Biomass Briquetting

As mentioned earlier, the tea industry is the largest firewood consumer in the country and it is supplied mainly from nearby rubber plantation or forests. Tea manufacturing requires, thermal energy as an input to two stages: withering of green leaves and drying. This heat is generally produced by direct combustion of firewood or fuel oil. Due to the high cost of fuel oil at present almost all the driers are being operated with firewood except in the hill country.

On average, 3 kg of wood, 0.7 kg for withering and 2 - 2.5 kg for drying is required to produce one kg of tea. In recent years, Sri Lanka produced about 211.3 million kg. of tea and it was estimated to have consumed 377.4 million kg of fuel wood as a whole. This is really a large amount of firewood and if this consumption pattern is allowed to continue, the effect on the environment and the ecology will be disastrous. However, tea production cannot be reduced since it is an important source of income to the country. Similarly, hotels and eating houses, brick and tile manufacturers, coconut oil producers, tobacco industries, bakers and other industries, presently depend largely on firewood and the most suitable substitute for firewood is the use of agricultural waste as fuel in a suitable form.

The main problem associated with the available biomass is the low bulk density. For this reason it should be utilized near the place of origin whenever possible to avoid high transportation costs. Also, some residues like coir dust have high moisture content and it has to be dried before being used as a fuel. Until recently, densificaftion or briquetting technology has been found to be economically not feasible as firewood is available at a cheaper price. But the present situation is different and the country appreciates the importance of introducing briquetting technology as a solution for the prevailing energy crisis. Several companies have already engaged in briquetting of biomass like husk and coir dust for export and for the local market.

## 10.5. NERD Centre Activities in Utilization of Agro Waste

Recently, the NERD Centre has introduced a wood gasifier system to the tea driers in order to make more efficient use of available firewood compared to direct combustion and has been able to reduce wood consumption to a certain extent. Also, the NERD Centre has developed a fluid bed husk gasifier and this system could be feasible in tea factories located in the low lands where rice mills are available nearby. A new portable type bakery oven at industrial level has been developed to bake bread and other pastry products using sawdust/paddy husk stoves as a source of fuel and it has several advantages over the firewood operated conventional bakery oven. A domestic type baking oven also has been introduced for baking purposes at household level. However, the agro waste has to be transported to the place where the industry is located, thus incurring a high transport cost. In this regard, the NERD Centre has undertaken a research project to develop a briquetting machine heated with a coir dust or paddy husks stove in order to reduce operational costs. Tests so far carried suggest a better performance in making briquettes from paddy husks or from a combination of husks and coir dust which has the high lignin content required for binding.

In conclusion, there is great scope for introducing briquetting technology to convert the underutilized agro waste into a useful fuel. Such a new energy system will be extremely beneficial to the country by helping to meet a significant share of the present energy demand.

# 11. WOOD AND CHARCOAL BRIQUETTING IN MALAYSIA

*Hoi Why Kong, Malaysia*

## 11.1. Introduction

The technology of briquetting is relatively new in Malaysia. The first briquetting plant in the country was fully operational around 1985 and was sited in Klang which is about 30 km from Kuala Lumpur. Subsequently, 5 other companies were set up to manufacture charcoal briquettes for export (Hoi 1989). The current status of the companies are summarised in Table 1:

*Table 1. Status of Briquetting Companies in Malaysia*

| Name of company | Current Status | Types |
|---|---|---|
| Syarikat Yoltan Sdn Bhd. | Operating | Charcoal |
| Syarikat Minang Energy | Operating | Charcoal |
| Syarikat MT Sdn. Bhd | Operating | Charcoal |
| Syarikat ABf Sdn. Bhd | Starting | Wood and charcoal |
| Syarikat Sondo Energy Sdn Bhd | Operating | Charcoal |
| Syarikat | Operating | Charcoal |

Briquettes are rarely used in Malaysia despite possessing superior qualities. Within the rural areas, charcoal briquettes cannot compete with the availability of cheap fuels such as wood residues, charcoal, kerosene and diesel. As an illustration, the market value for charcoal is about RM 0.30/kg while the cheapest charcoal briquettes available cost RM 1.20/kg. Within the urban areas, the low usage rate of charcoal briquettes is mainly due to the lack of market promotion rather than pricing. A random survey of 50 restaurants in the capital city of Kuala Lumpur indicated that they had no knowledge of charcoal briquettes for barbecuing. However, they stated a willingness to pay a higher premium for a better, cleaner and more convenient product.

Almost 100% of the briquettes produced are for export to S. Korea, Japan and Taiwan. As a result, 90% of the briquettes are in the form of charcoal briquettes as they are preferred over wood briquettes in terms of cost savings in transportation and storage. The rapid development in the wood briquetting industry in the country over the past few years has indicated that there might be a reasonable economic return on the production and sale of carbonised briquettes.

## 11.2. Types of Briquettes in Malaysia

There are generally 3 types of briquettes being produced in Malaysia. They can be classified as: (a) rice husk briquettes, (b) wood charcoal briquettes with a binder and (c) wood charcoal briquettes without a binder.

### Rice Husk Briquettes

There is only one rice husk briquetting company in the country. The company is located in the State of Kedah, about 350 km north of Kuala Lumpur. The company uses the Satake husk heated forming machine. This company developed the concept of continuously crushing and solidifying husk by high kinetic force and temperature. The solidified husk product is sold as Selco Doughnut. These briquettes are sent directly to Japan where they are pulverised into very fine powder to be used as a plasticiser. The machine has a production capacity of about 450 kg/h and can use raw husk with a moisture content of up to 12% on wet basis. The cost of the entire set-up of the plant is about RM 400,000 (Anonymous 1987, Anonymous 1989). The production capacity of the company is 200 tonnes per month. The specifications of these briquettes are as follows :

| | |
|---|---|
| Apparent specific gravity | 0.7 $kg/m^3$ |
| Ash content | 2.4% |
| Moisture content | 6-12% |
| Calorific value | 19.0 MJ/kg |

### Wood Charcoal Briquettes with a Binder

Another company manufactures about 10 tonnes/month of charcoal pellets from charcoal fines for local consumption using starch as a binder. This plant purchases charcoal fines from charcoal mills faced with the problems of storage and disposal. The fines are delivered to the plant in trucks and are then stored in open warehouses. The sizes of charcoal are graded by means of a vibrating sieve with a 0.3 cm top screen size. The bigger pieces are broken down into smaller pieces by means of a simple coffee bean grinder (Andrew & Lander 1987). Starch is the most common binder used. Starch paste is made in a separate cooking tank and is then pumped into the paddle mixer. The mixing formula is as follows :

| | |
|---|---|
| Charcoal | 73% |
| Starch | 5% |
| Calcium carbonate | 2% |
| Water | 20% |

The starch and charcoal are thoroughly mixed in a horizontal paddle mixer operating at a fairly low speed. When the starch and charcoal are uniformly mixed, the discharge end of the horizontal paddle mixer is then opened and the mixture is fed into a simple briquettor. The charcoal briquettor is basically a low pressure machine operating at a pressure of about 400 psi. The press is equipped with a vibrator to agitate the mixture constantly before it is briquetted. The briquettes are dropped from the press rolls onto a belt conveyor and carried to a dryer. The accepted commercial dryer is a single, horizontal conveyor which is loaded with wet briquettes at one end. Dry briquettes are discharged at the opposite end. Once the dry briquettes are sufficiently cooled, they are directly discharged into a bagging bin and sealed with a sticker. The bagged briquettes are sold in local night markets at a price of about RM 0.60/kg.

**Wood Charcoal Briquettes Without a Binder**

The most popular method of manufacturing briquettes in the country is via the unique screw feeder system. The wood briquettes obtained are carbonised in rectangular brick kilns to produce charcoal briquettes without binder (Hoi 1987). The distinctive features of this system are: (a) no binding agents are used and (b) the extrusion cylinder is externally heated to about 300$^0$C. Besides sawdust, other wood wastes such as bark dust, planer wastes, sander dust and chip dust in powder form are used as briquetting material. Sawdust is by far the most important material, comprising almost 70%. The use of other material is limited to 30%. In a certain company, a mixture of bark dust in briquettes at less than 30% concentration was used. It is said that this formulation makes the product more water resistant and improves strength properties. Depending on the species of wood used the apparent density of sawdust varies from 0.15-0.23. The average moisture content of the sawdust in Malaysia is about 45%. Thus to manufacture 1 tonne of briquettes in Malaysia, at least 1.8 tonne of sawdust is required. A typical set up of a plant that manufactures briquettes by this method consists of the following:

- A manual feeder with vibrating sieves for sawdust
- A rotary dryer
- A pneumatic conveying system with separator cyclone
- Briquetting machines
- Carbonising kilns

After the briquettes are produced they are carbonised in small rectangular brick kilns with efficiencies ranging from 20-25%. The physical size and shape of the briquettes are shown below:

| **Description** | **Length** | **Weight** | **Diameter (mm)** | | **Shape** |
|---|---|---|---|---|---|
| | | | Inner | Outer | |
| Wood briquette | 430 mm | 1.2 kg | 22 | 54 | Hexagon |
| Charcoal briquette (based on 20% conversion) | 310 mm | 0.4 kg | 15 | 40 | Hexagon |

The production capacity of a typical extruder is approximately 360 kg/hr.

The qualities of the charcoal briquettes and local wood briquettes are illustrated below in table 2:

*Table 2: A Comparison of Local Wood Charcoal and Charcoal Briquettes*

| **Characteristics** | **Local wood Charcoal** | **Charcoal Briquettes** |
|---|---|---|
| Burning time | 30-45 min/kg | 60-90 min/kg |
| Cleanliness | Dirty | Clean |
| Handling | Difficult because of non uniform size | Convenient because of standard size |
| Smoke emission | Yes | Yes |
| Calorific value | 31 MJ/kg | 32 MJ/kg |
| Pricing | RM 0.30/kg | RM 1.2/kg |

All the companies produce charcoal briquettes solely for export. Most of them already have confirmed orders for charcoal briquettes for the next 3 years.

## 11.3. Drawbacks of Screw Feeder Plants in Malaysia

**Machine Maintenance:**

Due to the abrasive nature of the sawdust, the briquetting machines require constant maintenance. The taper screw, for example, has to be sharpened or changed every week, which seriously affects the production rate. In more modern machines, the production capacity is improved by the use of a screw sleeve with the taper screw. Screw sleeve has the advantage that non-skilled personnel can change the sleeve within a short time. This arrangement allows the machine to be in continuous operation for a longer period.

**Raw Material:**

Variation in the moisture content in the sawdust often creates problems in the drying process. During the rainy season the moisture content of the sawdust is so high that the drying process requires more heat input. On the other hand, during the dry season, sawdust is sometimes overheated in the conveying line. Due to the set-up of the rotary dryer, there is no instrumentation to check the sawdust and flue gas temperature along the dryer. Variation in the species of sawdust also affects the quality of the briquettes produced. Sawdust of species such as Pulai (Alstonia spp.), Jelutong (Dyera costulata) and Rubber wood (Hevea brasiliensis) tend to give problems to the extrusion process when they are used alone. In order to overcome the problem, these species will have to be mixed with other species of sawdust.

**Environmental Problems:**

The briquetting process creates a lot of smoke inside the plant because of poor ventilation. Also, the exhaust gas from the carbonisation chambers is a serious source of pollution to the environment and a nuisance to neighbouring factories.

**Storage of Product:**

Uncarbonised briquettes tend to absorb moisture from the atmosphere during the rainy season and become loose. The combination of wet and loose sawdust poses a serious problem of disposal for the owner. On the other hand, hot and decarbonised briquettes sometimes do catch fire during storage.

## 11.4. Financial Analysis of a Typical Plant in Malaysia

**Estimated initial investment costs in RM (US$ 1 = RM 2.5)**

| | |
|---|---|
| Machinery | RM 900,000.00 |
| Land and building cost | RM 239037.00 |
| Working capital for<br>Labour cost RM 19650 x 3<br>Material stock holding cost RM 39400 x 3<br>General expenses RM 8000 x 3 | <br>RM 58950.00<br>RM 118200.00<br>RM 24000.00 |
| Total investment cost | RM 1340,187.00 |

**Sales revenue**

1st year contract sales 3600 MT @ RM655/MT RM 2358000.00
2nd year contract sales 4200 MT @ RM655/MT RM 2751000.00
3rd year contract sales 4200 MT @ RM655/MT RM 2751000.00

**Direct cost**

| | | |
|---|---|---|
| Raw material cost | 1 MT | RM 20 |
| Direct wages | 1 MT | RM 50 |
| Packing material | 1 MT | RM 55 |
| Transportation | 1MT | RM 150 |
| Upkeep of factory | 1MT | RM 20 |
| Electric motor | 1MT | RM 80 |

**Production cost**

| | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| Sales Revenue | 2358000 | 2751000 | 2751000 | 7860000 |
| Raw Material | 72000 | 84000 | 84000 | 240000 |
| Direct Wages | 80000 | 213000 | 254000 | 647000 |
| Power | 288000 | 336000 | 336000 | 960000 |
| Packing material | 198000 | 254100 | 279510 | 731610 |
| Transportation | 540000 | 693000 | 762300 | 1995300 |
| **Total Direct Cost** | 1278000 | 1580100 | 1715910 | 4574010 |
| Office rental | 12000 | 13200 | 14520 | 39720 |
| Telephone/Telegram | 24000 | 26400 | 29040 | 79440 |
| Office expenses | 12000 | 12000 | 12000 | 36000 |
| Travelling expenses | 48000 | 48000 | 48000 | 1440002 |
| Upkeep of factory | 72000 | 92400 | 101640 | 66040 |
| Salary and allowances | 120000 | 132000 | 145200 | 397200 |
| Depreciation | 150000 | 150000 | 150000 | 450000 |
| **Total Overhead** | 438000 | 474000 | 500400 | 1412400 |
| Total direct and overhead cost | 1716000 | 2054100 | 2216310 | 5986410 |
| Net profit | 642000 | 696000 | 534690 | 1873590 |
| % Return on sales revenue | 27.23% | 25.33% | 19.44% | 72.00% |
| % Return on total investment | 47.90% | 52.00% | 39.00% | 139.80% |

In the above calculations the following assumptions were made: The labour cost for the plant has been estimated by considering the requirement of skilled and unskilled labour throughout the year for both the operation and maintenance of the plant; direct wages are estimated to increase by 10% annually; raw material cost has been estimated from the yearly production of carbonised briquettes; due consideration was given for the weight loss during pre-processing and briquetting of the raw material; plant power cost was estimated from the energy requirement of each equipment and its operating period. Other assumptions made were a 10% annual increment in the cost of packing materials, transportation, office rental, telephone and telegram, upkeep of machinery and factory and salaries and allowances. The depreciation on machineries was taken as 20% of the fixed rate.

## 11.5. Conclusions

The healthy development of the briquetting industry will be dependent on the following factors:

- The analysis is based on very high committed sales in the export market. The financial analysis assumes the company will have a steady demand for its total briquettes production. However, over production or competition will cause its market share to drop and result in a sharp decrease in the financial viability of the industry.

- The most sensitive costs for briquettes production in Malaysia are those based on energy cost, availability of labour and a steady supply of raw material. Any adverse change or variation of these factors will invariably affect the viability of the industry.

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# 12. COMMERCIALISATION OF SCREW PRESS TECHNOLOGY THROUGH ENTREPRENEURIAL INVESTMENT

*Pradeep Chaturvedi, New Delhi, India*

## 12.1. Energy Scene in India

Over 70% of the rural population in India depends on traditional energy sources like agro wastes, dung cake and fuel wood. The total energy supplies including both commercial and non-commercial forms, increased from 82.7 mtoe in 1950-51 to about 291 mtoe in 1990-92. In this, the share of non-commercial fuels has declined form 74 per cent in 1950-51 to 41 per cent in 1990-91. Fuelwood accounted for 65 per cent of the total non-commercial energy consumed in the country. Thus non-commercial energy sources contributed 119 mtoe, of which fuelwood accounted for 77.5 mtoe (corresponding to 166 mt of fuelwood).

Fuelwood is supplemented by dung and crop residues in meeting energy needs in the rural areas. The annual availability of wet dung was estimated at 960 mt in 1990-91. Most of it is used in the form of low value dung cakes. Out of this, about 80 mt of dry cow dung is consumed as a fuel. The net annual availability (consumption) of crop residues, which can be used as fuel was estimated at about 50 mt in 1990-91, out of a total estimate of crop residue generated at 94 mt. Commercial and Non-Commercial Energy consumption proportions from 1953-54 to 1987-88 are given in Table 1.

*Table 1. Utilisation of Commercial and Non-Commercial Energy in mtoe (percentage shown in brackets)*

| Period / Type | 1953-54 | 1970-71 | 1980-81 | 1987-88 |
|---|---|---|---|---|
| Commercial | 21.02 (24.7) | 44.01 (34.8) | 72.7 (40.7) | 102. 0 (47.5) |
| Non-Commercial | 64.10 (75.3) | 86.80 (65.2) | 105.8 (59.3) | 112.6 (52.5) |
| Total | 85.1 | 133.2 | 178.5 | 214.6 |

Future proportions have been worked out by the Energy Policy Division of the Planning Commission of India in 1991 and are given in Table 2.

*Table 2. Total Energy Demand (Base Case) in mtoe (peercentage shown in brackets)*

| Period / Type | 1994-95 | 1999-2000 | 2004-05 | 2009-10 |
|---|---|---|---|---|
| Commercial | 132.2 (53.3) | 188.7 (61.5) | 255.6 (71.3) | 322.1 (79.4) |
| Non-Commercial | 115.7 (46.7) | 117.4 (38.4) | 102.8 (28.7) | 83.6 (20.6) |
| Total | 247.9 | 306.1 | 358.4 | 405.7 |

## 12.2. Biomass Use as Fuel in India

Biomass sources like fuelwood, agro-residue, urban/industrial waste and cattle dung met 38% of India's energy demand in the year 1993-94. Table 3 gives details of the contributions of different sources.

*Table 3. Biomass Use of Energy/Fuel in India (1991-92) (Million tonnes/year)*

| S.No. | Source | Availability | Estimated consumption | Deficit |
|---|---|---|---|---|
| I. | Fuelwood | 28.4 | 166.85 | 138.40 |
| II. | Urban/Industrial waste | 246.0 | Negligible | |
| III. | Agro Residue | 94.2 | 50.0 | |
| IV. | Cattle Dung | 960.0 | 80. 0 (Dry Wt) | |

The deficit in fuelwood availability has resulted in the denudation of natural forests which is a major cause of concern. There are different fundamental forms of bio-energy use, but attention in India is always focused on bio-energy use in the traditional sector for household cooking and heating applications. Fuelwood has also been used for traditional applications in rural industries and for certain industrial applications in urban areas. Traditional industrial applications include tobacco, tea, brick and pottery processing. Earlier the biomass feed-stock was available at a very low cost and, therefore, efficiency of use was hardly ever considered. No incentive was available for its conversion in an officient fashion. Even a 25 percent improvement in the use efficiency of fuelwood can mean a reduction of almost 40 million tones of fuelwood consumption.

**Future Biomass Fuel Demand**

The projected demand of biomass fuels by 2004-05 A.D. given by the Advisory Board on Energy is as follows :

| | | | |
|---|---|---|---|
| I. | Fuelwood | - | 300 - 330 mt/year |
| II. | Dung Cake | - | 199 - 221 mt/year |
| III. | Agro Residue | - | 90 - 104 mt/year |

These projections are based on fuelwood consumption at 8 per cent efficiency in normal wood stoves.

## 12.3. Problems in Large Scale Bio-Energy Use

The major problems with regard to bio-fuel technologies relate to the following :

- Competing uses of biomass
- Erratic availability of biomass
- Variable heat content
- Variable forms of the feed stock
- Availability of high efficiency conversion technologies.

Agro residues used as biofuels have been observed as a potential source for energy for some time. Their conversion into a suitable form was a problem in the past, but, with new technologies now available, this is becoming a very attractive proposition. One major reason for their economic viability is that the inputs cost of the investments for growth of agro residues are not added onto the residue supply. Whatever comes out of the agricultural produce is unavoidable and has to be biodegraded, if not utilised in some other form. It will be observed that of the about 94 mt of the agro residues available, about 44 mt is unutilised. The emphasis in our bio-energy conversion programme, therefore, should be on the direct use of this residue. The successful experience with the screw extruder technology, as modified at the Chemical Engineering Department, IIT, Delhi, makes it attractive for applications to utilise agro residues. However, this technology as yet has not been commercially proven under field conditions. But, clearly, it has a high potential. Placing our confidence in this technology, we have planned for a major thrust in the future in terms of commercialising the technology on the basis of entrepreneurial investment.

## 12.4. Proposed Project for Development and Commercialisation of Screw Press Technology

Jute and coconut are produced on a large scale in the Asia region and the four major producing countries are Bangladesh, China, India and Sri Lanka. This was also the reason for focusing the project in the Asian region. The significance of the project lies in the fact that over 3 mt per year of jute and keenaf is produced from about 2.5 million hectares cultivated by about 12 million medium size and marginal farmers in the Asian region for much needed cash. Asia also produces about 95 percent of jute and keenaf. About 18 mt of dry matter is produced to obtain 3 mt of jute and keenaf fibre. Of this about 3 mt of dry leaves are defoliated in the field and incorporated into the soil to recycle plant nutrients. About 7.5 mt of dry leaves are obtained by traditional stem retting. The balance, 4.5 mt of biomass, is lost in the retting water causing water pollution which gradually depletes after the cessation of retting. Major producers of coir are India and Sri Lanka. About 35 per cent of the coconut fruit is husk and 25 per cent shell. Coir is obtained by retting and extraction, leaving coir pith as a waste. The direct beneficiaries obviously are the large number of farmers and their families engaged in the production and processing of natural industrial fibres. At present, the farmers engaged in growing natural industrial fibre crops live at subsistence level and earn a direct farming income of about Rs. 900/- per month for six months a year only. The proposed project is aimed at developing and utilising briquetting technologies for producing briquettes from the residues and motivating local entrepreneurs to start industries using these briquettes as a source of fuel. Thus, ultimately, it will be through the network of locally available entrepreneurs that the technology will find greater use leading to larger incomes and an increase in employment generation opportunities in a decentralised fashion.

## 12.5. Conclusions

The promise held out by the recently concluded project by IIT, Delhi, strongly indicates the possibility of the technology being commercialised on the basis of entrepreneurial investments. However, the findings need to be cross-checked with the field conditions.

# 13. UNIDO THEMATIC PROGRAMME ON BIOMASS ENERGY FOR INDUSTRIAL DEVELOPMENT IN AFRICA

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## 13.1. Introduction

In the past 20 years United Nations Industrial Development Organization (UNIDO) has implemented 22 projects in Africa dealing with biomass utilization for energy purposes. The main areas covered include charcoal production, charcoal briquetting, biogas and gasification. The impact of this large number of projects must, however, be considered limited, due to the traditional adhoc project by project approach. At this stage, it is considered necessary, for a more effective and efficient approach, to adopt a thematic programme strategy for improving and increasing the sustaintable utilization of biomass for energy. The thematic programme outlined below will, in line with the UNIDO mandate, include : (i) biomass utilization for industrial energy; and (ii) the (small and medium scale) manufacture of equipment required for the conversion and use of biomass for industrial energy.

## 13.2. Industrial Biomass Use for Energy in Africa

Information on biomass used for energy in industry is available only in the Southern African Development Co-ordination Conference (SADCC) region. It is, however, expected that the situation in the SADCC countries is representative for Africa as a whole. In the 1990 SADCC energy balance, the importance of biomass energy for the industry sector is clearly shown. Total commercial energy use in industry is given as 105 PJ (Peta Joules), while the biomass fuels (wood and agricultural residues) supplied in total 109 PJ. Wood was by far the most important biomass fuel, covering 103 PJ, while the balance (6 PJ) was supplied by agricultural residues. Commercial energy supply for industry in the SADCC region is dominated by coal (36 PJ) followed by electricity (26 PJ). Since biomass supplies over 50 per cent of the industrial energy in the SADCC region, the economic dimension and importance of biomass energy for industrial development is obvious. As biomass is used for energy in particular in small and medium scale industries, the dependence on biomass for energy of the small and medium scale industrial sub-sector will be even substantially higher.

Many small scale industries such as brick, lime, tobacco and rubber industries use wood as their main and often only source of energy for the production process. Further, wood is used as for the industrial and artisanal production of charcoal, which is used as a cooking fuel and as an industrial raw material for the steel industry. Agro-industrial residues are used as industrial fuels, mainly in large-scale operations such as palm oil and sugar factories.

**Reasons for Current Use of Biomass Energy in Industry**

The trend of fuel switching as changes occur in the economic situation is apparent in industry. Industry energy usage, however, is not as flexible as for household energy. Climbing up the energy ladder from wood to commercial sources of energy in an improved economic environment has occurred in industry. Stepping down the energy ladder when the economic situation worsens is not very common. That in Africa at present over 50 per cent of industrial energy is still derived from biomass (predominantly wood) is not only a result of past economic trends, but is also a result of one or more of the following:

- burning of biomass forms an integral part of the production process
- biomass energy is cheaper than commercial energy
- biomass energy supply is more reliable than that of commercial energy
- low capital investment is needed for biomass based production systems
- biomass used is a waste product of the production process.

These reasons are discussed below in more detail:

Burning of biomass forms an integral part of the production process

In some processes such as the production of RSS (Ribbed Smoked Sheet) rubber and some kinds of tea and tobacco, the smoke of wood is essential in the production process. It gives a particular flavour or, as in RSS production helps to preserve the product as it prevents mould growth. In the small-scale production of charcoal from wood or agricultural residues, a part of the biomass is burned for generating the heat required for the carbonization process. In these and other processes energy derived from biomass is an essential and integral part of the production process and will, therefore, continue to be used in the future.

Biomass energy is cheaper than commercial energy

The comparative prices of commercial energy and biomass energy depend on many factors such as the world market oil price, transport distances and costs, availability of biomass and the government pricing policies. The pricing policy is of special importance in countries where governments apply full-cost pricing for commercial energy while this is not (yet) done for biomass fuels. If the more convenient handling characteristics of commercial fuels do not offset the higher cost, then the price difference may be the main reason for continuing to use biomass as the energy source in production processes.

In the period 1980 to 1985 when oil prices were high, some factories, especially the agro-industrial sector, converted their drying operations from commercial energy to biomass energy. A couple of years ago, many of these were converted the other way around. This illustrates that the price difference can be a main reason for selecting the energy source.

Biomass energy supply is more reliable than that of commercial energy

In a number of African countries supply of commercial energy is, because of a number of factors, not reliable. Biomass on the other hand can be produced at or near the factory, guaranteeing a stable supply. Industries traditionally using biomass as the source of energy may for this reason be especially reluctant to change to a commercial source of energy. If commercial energy is preferred because of price, convenience or product quality, the conversion to a system with a biomass energy back-up is possible to ensure reliability of energy supply.

Low capital investment needed for biomass based production system

For example, the traditional small scale production of bricks and tiles is based on biomass (wood). Conversion to commercial fuels would require relatively large investments and reduce the flexibility of production as it would be confined to one place. It is unlikely that these and similar small-scale enterprises will consider fuel switching to commercial fuels.

Biomass used is a waste product of the production process

Industries utilizing wood or agricultural products can produce residues for which no other use can be found. These materials need to be disposed of. If these materials have a heating value it may make sense to use them for generating heat or power, thereby, substituting commercial energy. Examples of this are the wood processing industry, and the palm oil and sugar industries, which use their wastes to generate steam for heating and power generation.

As discussed above over 50 per cent of industrial energy in Africa is at present still derived from biomass. Reasons for this have also been given. The use of biomass for energy, especially wood, is, however, causing problems. The main problem is the widespread deforestation and its associated impacts. Industrial use of wood is not the only and, by far, not the largest user of wood. Its contribution is, however, clear. In the SADCC region the industrial use of wood for energy comprises 9 per cent of total use of wood for energy. In the use of agricultural residues for energy, industry accounts for 12 per cent. In some countries these figures are substantially higher. The tobacco industry in Malawi alone, for instance, consumes 23 per cent of all wood used for energy. This Thematic Programme is designed to assist in improving the efficiency of the present industrial biomass energy use.

**Potential for Increased Use of Biomass Energy in Industry**

Despite the fact that there is a fuelwood crisis, huge amounts of biomass (including both wood waste and agricultural residues) are today still wasted or not utilized to their full extent. In many instances, if utilized efficiently, these resources could provide a substantially larger source of energy for use in industry.

In many African countries, a large proportion of the commercial energy has to be imported. Of the 50 African countries, 30 have to import over 75 per cent of their commercial energy requirements. Of these 30 countries, 23 have to import over 90 per cent of their commercial energy requirement. With limited foreign exchange, some of these countries are severely hampered in their procurement of energy for development. For instance, in Ethiopia and Malawi in 1990, commercial energy constituted 25 and 17 per cent of merchandise exports, respectively. The increase in oil price in 1990 showed again the vulnerability of oil-importing countries of Africa, particularly the least developed countries.

Many countries still rely heavily on traditional fuels. In 19 of the 30 countries mentioned above, traditional fuels account for over 75 per cent of total energy requirements. For 5 countries, traditional fuels account for over 90 per cent of total energy requirements. Per capita commercial energy consumption of these countries is typically 1 to 2 Giga Joules per annum, while the average for Africa as a whole and for the world is 12 and 57 GJ per annum, respectively. These countries cannot rely on imports of commercial energy for their development. One alternative would be the sustainable utilization of indigenous biomass resources for energy.

From the industrialization point of view, more efficient utilization of these biomass resources for energy could be of interest for the following reasons. It could:

- promote new industrial activities
- improve the economic performance of industries
- process industrial waste materials
- improve the sustainability of industrial activities.

Promotion of new industrial activities

Availability of sufficient quantities of biomass (waste materials) at one location can form the required energy resources on which new (small - and medium scale) industrial activities can be based. One example of this is the utilization of surplus bagasse residues for the production of charcoal briquettes intended to be used as a household cooking fuel. New biomass energy options can create a demand for equipment for direct combustion of biomass, such as furnaces and stoves, or for conversion of biomass to another useful fuel through carbonization, gasification, fermentation, liquefaction, etc.

Improvement of the economic performance of industries

As discussed above, in times with high or moderate oil prices (over 20 US $ per barrel) or for oil importing countries with limited foreign exchange it can be financially and economically feasible for some industries to substitute fossil fuels by biomass. This will mainly be the case for industries generating biomass residues or for industries located near a place where biomass (waste) is generated in sufficient quantities. Examples of the former are the cacao, coconut and wood processing industries, and examples of the latter are (small-scale) industries located near plantations with a certain rotation period or agro-processing industries which produce an excess of biomass waste.

Processing industrial waste materials

Industries utilizing wood or agricultural products can produce residues which must, because of their chemical properties or volume, be considered as waste materials. These waste materials constitute an environmental problem. Waste materials such as the bark of trees or coffee residues can contaminate waters. Others, such as rice husks and coir dust form huge mounds with their associated problems (fires, pests, etc.). Promotion of existing, available and proven biomass energy technologies can contribute to solving these problems.

Improving the sustainability of industrial activities

The main challenge to industrial activities in the future is to improve their sustainability. Biomass energy technologies can contribute to this in more than one way.

Biomass, when used to partially or fully substitute for fossil fuels, contributes to stopping a further increase of atmospheric $CO_2$ concentration and, thereby, improve the global sustainability of industrial activities. For oil importing countries it further reduces the dependency on these imports and their vulnerability to oil price increases and foreign currency shortages. Thus, it also improves the national sustainability of industrial activities.

In particular, using agricultural residues contributes to combating deforestation. It, therefore, contributes to improving the sustaintability not only of the specific industrial activity, but also of the country and the world community as a whole.

The combustion of fossil fuels releases around six GtC (giga tons of carbon) each year. Tropical deforestation has been estimated add more than two GtC to the annual total. About 3.5 GtC of these man-made emissions accumulate in the atmosphere and the remaining part is absorbed in the oceans.

Carbon dioxide is not the only greenhouse gas. Other important greenhouse gases are CFC's, methane, nitrous oxide and ozone. However, $CO_2$ is by far the most important single greenhouse gas, contributing 45 to 55 per cent to the greenhouse effect. The increase of atmospheric $CO_2$ concentration must be mainly attributed to the combustion of fossil fuels and to deforestation. The contribution of the combustion of fossil fuels to the greenhouse effect is 31-38 per cent, while deforestation contributes 9-11 per cent.

Also, substitution of sustainably grown fuelwood (fuelwood plantations and tree crops) by agricultural residues can improve the sustainability of a particular industrial activity since it reduces the dependency on a fuel with many different applications and for which the demand is high and is increasing (for instance rubberwood).

## 13.3. Problem Areas

In analyzing the problems related to the use of biomass energy in industry in Africa, a clear distinction between two aspects is necessary. These aspects are (i) the inefficient traditional use of biomass, and (ii) the limited use of new biomass energy technologies in industry. Both aspects reduce the potentially available biomass resources for industrial energy. The inefficient use of traditional biomass leads also to deforestation while the limited use of new biomass energy technologies in industry results in an increased consumption of commercial fuels. The inefficient use of traditional biomass is exemplified in particular with the use of log wood in small and medium scale industries such as the brick, tobacco and rubber industries and in charcoal production. The limited use of new biomass energy technologies in industry refers to technologies such as gasification, fermentation, briquetting and combustion of, in particular, agro-industrial and wood wastes.

The biomass energy programme addresses both aspects. However, the emphasis is on improving the efficiency of the traditional use, as the largest impact and quickest results are expected in this field. Successes with promotion of new biomass energy technologies in the past have been limited. However, some of the new technologies have proven to be feasible and are applied and operational in developing countries. These "new" and proven technologies will also be promoted in the programme, where it is found appropriate to do so.

The main causes for both the inefficient use of traditional biomass and the limited use of new biomass energy technologies in industry are described below.

**Inefficient Use of Traditional Biomass**

The most important reasons that improvements in the efficiency of traditional biomass use have not occurred on a sufficient scale are discussed below:

Insufficient awareness of possibilities to improve the efficiency

To consider biomass energy efficiency improvement measures there should, in the first place, be an awareness of possibilities to improve the efficiency. This awareness can be created by provision of information by governmental and non-governmental bodies.

Insufficient incentive to improve the efficiency of traditional biomass use

Efficiency improvement measures will only be implemented if there is a sufficient incentive. The benefits must outweigh the costs. Cost and benefits are not restricted to financial terms, but also include social aspects. The cost-benefit analysis is not always based on objective criteria. The perception of costs and benefits plays an important role.

If energy is only a small part of the total production cost, interest in energy improvment options may be small. One of the reasons for low biomass energy cost can be the fact that full- cost pricing is not applied. The cost is only based on labour, transport and marketing cost. Replanting and forest management costs are very often not taken into consideration. Another aspect that normally is not taken into consideration is the relation between product quality or yield and proper energy management not only conserves wood and therewith saves money, but can also increase the production ratio of cured to green tobacco leaves. This latter advantage produces even greater cost benefits than does the reduction in fuelwood usage.

Wood energy based industries compete with households for fuelwood resources. The consequences of deforestation are much more severe for, especially, poor households than for the industries. It is, therefore, the social responsibility of wood based industries to implement efficiency improvement measures. Creation of awareness of the magnitude of savings achievable by energy efficiency improvement measures and the consequences for the community in which they operate may create an additional incentive for industries to take action.

Limited financial resources to implement efficiency improvement options

Limited access to loans for efficiency improvements of traditional biomass use is considered to be caused in the first place by the lack of awareness of loan possibilities and the insufficient capability of industry to prepare proper investment plans.

Insufficient national capabilities to implement improved technologies

Promotion of, and assistance in implementing, energy efficient improvement can be done by government extension institutes, industry associations, national consultancy firms and/or universities. The government has in any case a role in the establishment of the extension and support system.

**Limited Use of New Biomass Energy Technologies in Industry**

Insufficient incentives to use new biomass energy technologies in industry

New biomass energy technologies imply normally the use of a fuel less convenient to handle than commercial fuels. Further, the demand on management capabilities is increased, as it requires more work to organize handling, collecting and storing. Labourers may oppose this change as it normally increases their workload and results in less favourable working conditions. Energy costs are often only a small part of the total production cost. Therefore, especially for small and medium scale enterprises the total gain does not easily compensate for the additional effort. In addition, due to governments subsidizing commercial (fossil) fuels, new biomass options are in many cases not financially viable. Finally, there are in general not many examples known to individual entrepreneurs that prove the success of new biomass energy based projects.

Inadequate support-extension system

The importance of an operational support-extension system is very often underestimated. Traditional sources of energy very often do not play a role in the national development plans. The governments do not allocate a sufficient part of their scarce resources to this issue, and commercial national consultancy services from the private sector in this field are not developed. A proper functioning support-extension system is crucial for the wider scale utilization of new biomass energy technologies for industrial development. Such a system can also play an important role in creation of awareness of the possibilities of using these technologies. In this respect the role of unviersities and national research institutes could be strengthened.

Insufficient financing possibilities for new biomass energy technologies

Financing of new renewable energy options, which are normally small-scale options, is much more costly than financing of commercial energy options. The risks perceived limit the possibility of obtaining loans and if loans can be obtained, the interest normally is much higher than needs to be paid for other types of investment.

This problem is now recognized and there is an international movement to tackle this. The USDOE/World Bank initiative FINESSE (Financing of Energy Services for Small-scale Energy-users) has been set up to overcome this problem by integrating renewable energy components into larger sector loans of the World Bank or regional development banks. The other problems of unawareness of loan possibilities and insufficient capabilities of industries to prepare a proper investment plan as discussed above also play a role.

Limited access to new biomass energy technologies

Although flows of information have become immense, there is still a lack of specific, concise and comprehensive information on renewable energy technologies, including new biomass energy technologies. Provision of the required information would increase the access to these technologies.

Developing countries can not rely on importing required equipment. For use on a wider scale, equipment needs to be manufactured locally. To design again different systems would be an unnecesary repetition of efforts made by others in the past. Mistakes made would be repeated and money would be wasted. However, to acquire the property rights of systems proven to work for a particular application is difficult. In the beginning of the eighties, when biomass energy was considered one of the important alternatives to expensive imported oil, many new biomass energy technologies were developed, many with support from different governments. Some of these new technologies were developed mainly for developing countries. With the decrease of the oil price in 1986, companies which developed and manufactured this equipment went bankrupt. As a result the knowledge gained and designs made were lost. Entrepreneurs presently manufacturing equipment are reluctant to license their systems, they are also afraid of illegal copying and of losing a potential market.

*Participants' analysis*

In the participant analysis the following main actors were identified.

- biomass energy using industries.
- biomass (waste) generating industries.
- industrial energy users with biomass energy potential.
- research institutes (research and provision of information).
- industry associations.
- private consultancy companies for biomass energy technologies (existing or potential).
- equipment manufacturers for utilization of biomass for energy (existing or potential).
- banks.

The Thematic Programme on Biomass Energy for Industrial Development in Africa will work mainly with the above identified factors.

*Focus*

Based on the problem and participant analysis the Thematic Programme on Biomass Energy for Industrial Development in Africa will focus on the following activities:

- Collection, analysis and publication of information on total biomass resources and biomass availability for energy.
- Collection, analysis and publication of information on present and potential use of biomass for energy.
- Comparison of the social, economic, technical and environmental aspects of the biomass energy option with other renewable energy options and non-renewable energy options.
- Preparation and provision of information on new and improved biomass energy technologies and equipment.
- Training of trainers (extension workers, industry associations, research institutes and private consultancy companies) in:
  - new and improved biomass energy technologies.
  - monitoring of new and improved biomass energy technologies; and
  - preparation of investment plans for new or improved biomass energy technologies.
- Organize training courses to be conducted by trained trainers in the same fields as above.
- Monitor and improve the training courses conducted by the trained trainers.
- Provision of information, training and advisory services to (potential) manufacturers of equipment required for using biomass for energy.
- Demonstration of new and improved biomass energy technologies.
- Monitoring achievements of new or improved biomass energy technologies.
- Provision of technical assistance with the aim to demonstrate this activity to the people who will in the future give this service on a commercial or non-commercial basis.
- Provision of information to the government on the impact of government policy on the development of new and improved biomass energy technologies.
- Identification of financing possibilities for new and improved biomass energy technologies and disssemination of this information.
- Preparation and provision of information material to banks on the potential of biomass energy technologies.

## 13.4. Special Considerations

The Thematic Programme on Biomass Energy for Industrial Development in Africa addresses two aspects related to biomass energy (i) improvement of the efficiency of traditional use of biomass, predominantly fuelwood, for energy, and (ii) utilization of biomass wastes (including both wood wastes, agricultural residues, etc.) for energy. The ultimate goal of the programme is to contribute to the promotion of sustainable industrial development of, in particular, small and medium scale industries, based on indigenous renewable energy resources. This can be achieved through:

- Improvement of the energy efficiency of the biomass based industries.
- Utilization of biomass waste for energy to replace wood or non-renewable fuels.

- Promotion of new industries based on sustainable grown biomass.
- Reduction of the vulnerability of developing countries to oil and foreign currency crises.
- Processing of industrial biomass waste materials.
- Reduction of $CO_2$ liberation to the atmosphere; and
- Reduction of the rate of deforestation and desertification.

The Thematic Programme on Biomass Energy for Industrial Development in Africa will contribute to the implementation of the UNIDO medium-term plan (PBC.8/10, 6 May 1992) regarding the priority problem area of Environment and Energy as it will focus on energy conservation as well as the utilization of biomass for energy, one of the renewable sources of energy (paragraph 97). This is further specified in the UNIDO Environment Programme, Response of UNIDO to Agenda 21 (IDB. 10/32 of 21 September 1992, paragraph 16 and 25). In terms of Agenda 21 biomass energy can contribute to the protection of the atmosphere (Chapter 9, paragraph 16), and combating deforestation (Chapter 11, paragraph 25). It will, further, contribute to Chapter 34 (environmentally sound technology, cooperation and capacity building). The special emphasis in this respect will be on technology transfer.

In the evaluation of the wood energy activities within the Nairobi Programme of Action, which was adopted by the United Nations Conference on New and Renewable Sources of Energy which met in Nairobi, Kenya in August 1981, it was concluded that considerable work remains to be done in this field. Especially it was mentioned that rural industries did not yet receive the desired attention. The policy areas for concerted action in the future include dissemination of improved wood energy conversion devices for rural industries and for small enterprises, promotion of improved charcoal production systems, promotion of substitution of fossil fuels by fuelwood/charcoal and carrying out and implementing wood energy conservation audits.

## 13.5. Substantive Approach

The thematic programme "Biomass Energy for Industrial Development in Africa" provides an outline of specific country level activities that could be carried out by UNIDO in a number of African countries. In accordance with the UNIDO medium-term plan (paragraph 101) the programme will aim at (a) increasing awareness of management/government in the participating countries of biomass energy options: and (b) provide technical support to the participating countries infrastructure, including the estiblishment of industry related research and development institutions and the establishment of maintenance and repair capabilities. The programme is initially designed for countries importing a substantial part of their commercial energy requirements and having a large biomass resource base. The programme is considered especially beneficial for the least developed countries satisfying the above criteria. At the country level, activities consist of three phases (i) needs and opportunities assessment: (ii) programme planning; (iii) country level programme implementation. In phase I, the specific needs of a country will be assessed. Based on this assessment it will be decided whether or not to continue with phases II and III. In phase II, a workshop will be conducted in the country to plan in detail the activities that are to be carried out in the country. In phase III, the country specific activities will be executed. The total cost of the programme for one country in Africa is estimated to vary between US $ 4,00,000 and US $ 1,200,000 depending on local factors such as existing government policies, existing extension services system, biomass resources, etc.

**Programme Planning**

In view of the many parties involved and to ensure their participation an in-country workshop will be organized to review the draft country level programme prepared in phase I and to develop the overall approach. The UNIDO Objective Oriented Project Planning (OOPP) method may be used to clarify objectives and linkages and reach agreement on required activities. As many as possible (and practical) relevant actors will be invitied to participate in this project planning workshop. These include, among other, representatives of relevant government and non-government institutes, companies, representatives of private and public sector organizations involved in biomass energy, equipment manufacturers and suppliers, banks, academica with links to biomass energy and representatives of user groups, with a special emphasis upon the role of women. The participants will be selected in phase I. The outcome of the workshop will be used to formulate a detailed country level programme.

**Country Level Programme Implementation**

At the country level the biomass energy programme may consist of up to four modules:

Module 1 : Improvement of charcoal production methods.
Module 2 : Improvement of efficiency in industrial use of wood as a fuel.
Module 3 : Promotion of industrial utilization of agricultural residues for energy.
Module 4 : Promotion of micro-biological conversion of biomass to methane or alcohol.

## 13.6. Programme Strategy

Enhancement of the awareness of governments, industry associations and enterprises, on aspects related to biomass energy and institutional strengthening are the key elements in this programme. The enhancement of the awareness of governments will take place through advisory services and provision of information. The institutional strengthening will be done through training, provision of equipment and training materials, demonstration and study tours. The extension institute(s) and/or industry associations in turn have to conduct training courses for relevant groups in the country. A large number of these courses are part of this programme. In this way the assistance required for preparing course material can be provided, the achievements can be evaluated and, when necessary, adjustments can be made. Upon completion of the project the extension institute(s) and/or industry associations should have acquired all necessary information, knowledge and experience for carrying out the extension services on its own in a substainable manner.

It can be expected that experience will rapidly accumulate so that future country level programmes will benefit. Materials developed for one country can be transferred to other countries, after adaptation if needed. Experience gained with the development of equipment for one country can be used in other countries. Expertise from countries which already have implemented the programme may be used in other African countries and study tours to these countries may be a possibility. The programme will systematically search for and develop such opportunities.

The main target beneficiaries are of course the small and medium scale enterprises (private and public) which are in the position to improve their operations through more efficient use of biomass for energy, or through the utilization of biomass waste for energy. The programme will achieve this through the strengthening of the extension institute(s) and/or industry associations. In addition the programme will work with policy makers, institutional staff and representatives of public and private sectors to promote appropriate policies and development of biomass energy applications.

## 13.7. Objectives

**Development Objective**

The development objective of the Thematic Programme on Biomass Energy for Industrial Development in Africa is:

- to improve the efficiency of existing (small-scale) industrial wood energy systems in Africa in order to save at least 200 PJ at present production levels by the year 2010 (the present estimated level of industrial wood energy use is 1,000 PJ)
- to increase the (small-scale) industrial use of non-wood biomass wastes (agricultural residues, dung, etc.) for energy in Africa from the estimated present level of 250 PJ to 375 PJ by the year 2010 in a sustainable manner.

**Immediate Objective I**

Enhanced awareness of governments, industry associations and enterprises of the importance and potential of biomass energy as a renewable indigenous source of energy for small-scale industrial development, and understanding on the required support for promotion of the sustainable utilization of this potential.

**Immediate Objective 2**

Strengthen extension institute(s) and/or industry associations providing promotion, training and extension services to specific target groups in order to:

- improve the efficiency and quality of charcoal production
- improve the efficiency of the use of wood as a fuel in small scale industries
- promote the use of agricultural residues for energy
- promote micro-biological conversion of biomass to methane or alcohol.

## 13.8. In-House Co-operation

The Thematic Programme on the Use of Biomass Energy for the Industrial Development in Africa will be implemented by the Chemical Industries Branch in cooperation with the Environment and Energy Branch. However, promotion of increased utilization of biomass for energy purposes in Africa is a complex task which calls for a real multidisciplinary approach. Therefore, close cooperation will be sought with other groups within UNIDO, relevant to the subject. The following groups have expressed their interest in participating in the Thematic Programme on Biomass Energy for Industrial Development in Africa:

- Integration of Women in Industrial Development Unit
- Africa Programme
- Engineering Group
- Agro Industries Branch
- Technology Management Service

Depending on the particular conditions in a specific country, additional groups like Least Developed Countries Unit, Small and Medium Enterprises Branch, Human Resource Development Branch, Feasibility Studies Branch may participate in this programme. In addition, close cooperation with Financial Management Division (FMD) will be maintained in order to enable the mobilization of funds for the programme.

## 13.9. External Co-operation

At present there is no international organization dealing specifically with biomass energy utilization for industrial development. The topic of biomass energy in general is addressed in a number of projects from well known international institutions such as ESMAP (Energy Sector Management Assistance Programme of UNDP/WB) and FAO, and bilateral organizations.The main focus of projects including biomass energy is still on household energy. In the execution of the UNIDO Thematic Programme on Biomass Energy for Industrial Development in Africa, close cooperation will be sought with these and other institutions. Where wood is a main raw material, complementary forestry activities to ensure sustainable use of wood will be a major subject for cooperation with FAO. Further, the programme will seek close cooperation with well established and relevant institutions in Africa dealing with biomass such as TAU (Technical and Administration Unit of SADCC), AFREPREN (African Energy Policy Research Network) and others. All these intitutions will be invited to participate in the formulation and execution of the programme.

# 14. BIOMASS BRIQUETTES - A POTENTIAL BIO-ENERGY SOURCE IN INDIA

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## 14.1. Salient Features of Using Fuel Briquettes

- Easy to burn - lower ignition temperature compared to coal. Smokeless burning and sustained combustion and the temperature requirement is achieved due to very efficient combustion. Leaves only white ash without any fixed carbon. Full heat value is utilized.
- Easy to handle and 1000 kgs of briquettes per cubic meter can be stored and transported against 50 kgs of agro-waste.
- No pollution to the environment and no toxic gas and sulphur emission and even no odour.
- Very low ash content as low as 2 to 5% compared to 30 to 49% in coal.
- No binder is used.
- The natural polymer lignin acts as a binder and provides mechanical support and also provides resistance to decay and repels water.
- Very well suited to gasifiers which can run any engine because of the combustion efficiency and solid form.
- In gasifiers the briquettes can be used and the partially pyrolysed briquettes can be again used as a substitute for high value added charcoal for domestic and industrial use leaving the fuelwood unutilized and thus avoiding deforestation.
- These briquettes are used very efficiently in `PRIYAGNI' stoves invented by Central Power Research Institute, Bangalore.
- A typical usage of briquettes made out of paper mill sludge mixed with iron sludge power is made in big furnaces to keep the temperature alive for easy start up.

## 14.2. Social Benefits

*"A TREE SAVED IS MORE THAN A TREE GROWN".*

- The above Bio-Message is very clear. We need not spend more energy and money to grow more trees if we could avoid using them. Thus, all ecological disaster arising from deforestration can be checked.
- Saves the environment from pollution, all conventional fuel pollutes the atmosphere.
- Avoids using conventional resources like coal which means that future generation will not be deprived of its utility.
- Very precious hard earned and valuable foreign exchange need not be spent on petroleum imports. This will make the country's economy very strong and as a result our own currency will get stronger and our purchasing power will increase.
- Money spent on forestration programmes can be minimised or more land can be forestated.

- Due to efficient utilization of agro-waste, agriculturists will receive some income from their agro-waste, will make their farming more remunerative and attractive and thereby their standard of living will be improved.

## 14.3. Energy Chart and Its Cost - Cost Analysis

**Specification of binderless technology extrusion briquettes**

| | | |
|---|---|---|
| Calorific value | : | 4500 to 4800 kcal/kg |
| Diameter | : | 70 mm |
| Length | : | 450 mm |
| Weight: | : | 5.33 kgs per meter |
| Moisture | : | 7% |
| Ash content | : | 5-7% |
| Sulphur & phosphorous | : | Nil |
| Packing | : | 25 kgs polythene bag |

**Energy chart of different fuels**

| | | Heat value kcal/kg | Price per kg (Rs.) | Price per 1000 kcal (Rs.) |
|---|---|---|---|---|
| i. | Fuel briquettes | 4500-4800 | 0.70 | 0.16 |
| ii. | Soft wood (not timber quality) with 30% moisture | 1650 | 0.44 | 0.27 |
| iii. | Hard wood (not timber quality) with 30% Moisture | 2400 | 0.60 | 0.29 |
| iv. | L.P.G. | 7200 | 3.70 | 0.51 |
| v. | Coal | 4000 | 0.90 | 0.23 |
| vi. | Electricity (1000 Watts) | 860 | 1.00 | 1.16 |
| vii. | Carbonized charcoal briquettes | 6000 | 2.00 | 0.33 |

We can see that the fuel briquettes are the cheapest, most convenient energy source. The cost of coal is almost comparable, but its availability, wagon movement, quality and transit wastage are completey uncertain.

Trials were made in a local dyeing factory. Two similar dyeing drums were selected. Green colour dye was applied on a fixed quantity of yarn. Both the furnaces were situated side by side and all the firing conditions and other conditions were similar.

| | | |
|---|---|---|
| Cost of fuel briquettes | : | Rs. 1500 per ton |
| Cost of fire wood (15% moisture) | : | Rs. 800 per ton (moisture loss & cutting charges not included) |
| Basis | : | 30% moisture fire wood per ton is Rs.800 + cutting & wastages Rs. 60. Thus total cost is Rs. 860. |

**Consumption**

| | | | | |
|---|---|---|---|---|
| 15% Moist fire wood 202 kgs | - | Cost 202 x 0.86 | = | Rs.173.70 |
| 7% Moist briquettes 101 kgs | - | Cost 101 x 0.50 | = | Rs. 151.50 |
| 8% Moist fire wood 163 kgs | - | Cost 163 x 100 | = | Rs. 163 |

| | | |
|---|---|---|
| Using briquettes % of cost saving over fire wood of 15% moisture | = | 33 |
| Using briquettes % of cost saving over fire wood of 8% Moisture | = | 29 |

Trials were made in a local dyeing factory for preparing dye concentrate. A small brass vessel was used. Both the chullahs were identical and 8 batches of dye concentrate was prepared.

| | | | | |
|---|---|---|---|---|
| Cost of Leco (carbonized charcoal) consumed | : | 16 kgs x Rs. 3.00 | = | Rs. 48.00 |
| Cost of fuel briquettes consumed | : | 21 kgs x Rs. 1.50 | = | Rs. 31.50 |

Thus percentage of saving using fuel briquettes = 35%

This cost saving is apart from the convenience of very good combustion, temperature maintenance, time saving, smokeless environment and clean space saving. Normally fire wood consumption is unknown as it is brought in bulk and consumed again in bulk. Using briquettes the cost of energy can be calculated very easily as it is packed in 25 kgs packing.

## 14.4. Suitable Technology

There are many technologies like screw press, piston press, hydraulic press and roller press available for briquetting the biomass and the normal process is as follows: the agro-waste should be properly dried through some suitable drier to have a moisture content from 10 to 15%; the material is then crushed to bring it into uniform particle size. Many agro-waste are available in uniform size and need not be crushed. After the technology is chosen other parameters can be fixed.

## 14.5. Role of Government Agencies

- Appropriate technology for briquetting of biomass should either be developed indigenously through R&D organisations and various funding programmes on briquetting should be established.
- Import of briquetting technology and capital goods should be allowed for another 10 years at least to enable access to new technology. There should be no licensing formalities and it should be brought in under O.G.L. There should not be any customs tax or, duty on imported machinery or, spare parts or necessary ancillary equipments.

- There is an anomaly that briquetting machines are not considered to be alternative energy devices or renewable energy devices producing energy. In the schedule given by IDBI Letter No. 1617/RD pro (i) 82/83 Circular No. F.1-81-8, Circular No. F1 -16/81-82, it is mentioned in point No 15 as `Agricultural and Municipal Waste Conversion Devices producing Energy'. It is argued that briquetting machines do not produce energy directly. Bio-gas plants too do not produce power directly, but the gas is utilized in a burner to produce heat energy. Boilers using rice husk were given exemption but the boilers only produce steam. If gas, coal, electricity can be accepted as energy then why not fuel briquettes? There is a need to declare the briquetting machine as an renewable energy system.
- A visit to other countries to study the technological advancement in this area can be arranged and the Government of India can sponsor this programme. Teams of government officials, people from R & D departments, entrepreneurs engaged in briquetting industry can also be invited to participate in the study tours.
- Briquetting industry should be given top priority in the matter of electricity connections and supply. No power cut should be applicable. All State Electricity Boards may be suitably advised.
- The decision of the Government is to be implemented as a top priority without any hesitation and avoid undue delay to achieve this wrthy object of Bio-Energy. For example, under Central Excise Rules 1944, Central Government has exempted the goods specified in the Table under No. 68 point No. (XIV). But the central excise authorities refused to give exemption stating that briquetting machines are not producing energy but only briquettes which may produce energy if used in a boiler and so an. This needs to be clarified. Even people who have bought the briquetting machines from National Small Scale Industries Corporation paid central excise for their machines.
- All the state governments have started nodal agencies for energy development through the Central Government's assistance. These agencies must be asked to play a vital role and contribute to the purpose for which it has been established instead of acting as a routine office to MNES.

## 14.6. Financial Incentives

- Right now the central and state governments provide a capital subsidy amounting to 10% to 25% depending on the location of the industry in backward areas. The government should consider giving a subsidy of 33.3% as is given for Solar Thermal Projects. Such a subsidy should be irrespective of the industry's location, backward area etc.. This is a basic necessity because this industry should be located in a place where raw materials are abundantly available and where there is a market for the briquettese.
- Indigenous briquetting machines should be exempted from excise, central and state sales taxes.
- The fuel briquettes should be exempted from central excise for 10 years at least.
- All state governments should be asked to exempt fuel briquettes from the preview of the sales tax irrespective of its use, i.e. domestic or industrial.
- In order to encourage consumption of briquettes a consumer subsidy of Rs. 50 to 100 per ton of briquettes consumed or produced may be considered.
- Railway freight concession may be given to fuel briquettes as in the case of coal.

- Freight equalization scheme may be introduced to induce entrepreneurs to establish this industry in locations where the raw material is available, even though the briquettes consuming centres are located elsewhere.

## 14.7. Marketing Strategy for Fuel Briquettes

- The Government of India through MNES should propagate the advantages of using fuel briquettes producing energy through alternative sources.
- All public sector undertakings may be asked to use fuel briquettes at least to the extent of 10% of their conventional fuel consumption.
- Conventional fuel companies like Indian Oil, Bharat Petroleum, Coal India, should promote the uses of Bio-Energy in all their letter heads, advertisements, invoices and other materials.
- All nodal agencies should conduct an essay competition for school children to spread the message of Bio-Energy. It can even be incorporated into their educational lessons.
- All other possible efforts to encourage the use of bio-energy or at least to make people aware of it should be made.

## 14.8. Banker's Assistance

- Now IDBI operates the Refinance Scheme for Small Scale Industries, through commercial banks. Clarification regarding treating this briquetting technology as `Agricultural Waste Conversion Devices producing Energy' to avoid ambiguity and misinterpretation is needed.
- IDBI may refinance the banks to the extent of 100% refinance to encourage banks to offer assistance.
- Repayment holiday should at least be given 3 years from the date of first disbursement.
- Repayment period should be extended upto 10 years as this industry has to bear a high fixed cost.
- The rate of interest charged to this industry should only be 6% to attract more investment and to make the industry viable.
- Any other suitable measures to encourage the production of fuel briquettes should be taken up.

# 15. EXPERIENCES OF BRIQUETTING IN PUNJAB

*Wg. Cdr. G.P.S. Grewal, Punjab, India*

Punjab is an agricultural surplus state. It is also aptly called the granary of India. However, over the last two decades, besides being the largest producer of wheat, it has also started producing rice. It is therefore natural for anyone to assume that there will be an enormous amount of "agro residues" available from harvesting wheat and rice which can be diverted as feed material for briquetting. However, actually, the position is at variance with these assumptions which is discussed in detail in subsequent paragraphs.

Wheat is grown in the whole of Punjab while rice is grown in 85% of the state. Since yields of both crops are higher here when compared to other areas of the country, agro residues are also produced more abundantly in this state. Wheat harvesting generates wheat straw. This material will never be available for "briquetting" for the simple reason that it has been used as dairy cattle fodder since time immemorial. This leaves only rice husk as another "agro residue" which is potentially available for briquetting. Punjab is far away from the coal producing centres of the country, so not only is coal scarce, it is also very costly. As a result industry in Punjab has been buying rice husk in a big way for the last 15 years. Thus an agro residue which was available almost free of cost 15 years ago has become very expensive.

Today, the average cost of rice husk in Punjab is over Rs.850 per ton. This price is beyond the reach of any one who intends to start a briquetting plant with rice husk as raw material. Once overhead costs are added the cost of the finished product is so high that there are no margins for the briquetter to earn his living.

However, burning rice husk directly creates enormous pollution. There have been a number of complaints by the people and finally the state government decided to intervene. By a notification the state government gave 15 months for the industry to switch over to alternative fuels for their energy requirement. The only concession that the state government has allowed is that if the boiler furnaces are fluidised, loose burning of rick husk will be permitted. The ban has become effective with effect from 1st April 1995. One has to really wait and see at least for a month to know whether the state government will stay firm on its decision or not. In the case that the government holds its ground, then an abundant quantity of rice husk will become available. Since rice husk will not be burnt directly, the price is expected to fall sharply, say to around Rs. 400 a ton. At this price it becomes a major source of raw material for briquetting. However, direct briquetting of rice husk is uneconomical, because in untreated form it is highly abrasive. But, due to research carried out by I.I.T. Delhi, i.e. preheating it to make it softer and grinding it to increase its bulk density for better output it has become the most acceptable and convenient material for briquetting. If the ban on loose burning remains then the briquetting industry in Punjab has a good future and is likely to prosper because industry will have no other choice but to buy them for their energy needs. All those entrepreneurs who are intending to enter the briquetting field are advised to wait for some time till the issue of the ban is finally decided.

At the moment, the briquetting industry in Punjab is passing through a difficult phase because it is dependent on saw dust for its survival. This item is scarce and expensive. The industry is not able to expand because of raw material shortages. In fact it is not even able to run beyond 8 hours. Under these conditions any further addition in capacity will only aggravate the situation. However, if the state government sticks to its principled stand of not yielding to pressures to relax the ban on burning rice husk, these will soon be an opportunity for expansion.

# 16. ESCAP'S ACTIVITIES ON NEW AND RENEWABLE SOURCES OF ENERGY

*Kyi Lwin, ESCAP, Bangkok, Thailand*

## 16.1. Introduction

Over the past decade, the developing countries of the region have made efforts to develop and utilize new and renewable sources of energy (NRSE) within the framework of the Nairobi Programme of Action, in order to reduce dependency on imported fossil fuels, and to solve the problem of environmental degradation. In most countries, NRSE programs emphasize technologies pertinent to rural development and particularly to providing energy for rural areas. Despite the current low oil prices, NRSE are being increasingly used by the developing countries, with biomass, solar, wind and mini hydro being the more commonly used renewable sources in the region (1-3).

Technologically, the technical development of certain renewable energy technologies has made remarkable progress during the past decade, and for most of these, the outlook for continued improvement is good. They are likely to make an increasing contribution as an addition to existing energy sources (1-3).

The remarkable technological advancements made in certain renewable technologies during the past decade indicate that an energy future making intensive use of NRSE is technically feasible. But the transition to NRSE has been progressing slower than envisaged especially in the context of developing countries. International cooperation for efficient introduction and diffusion of successfully demonstrated technologies in the field of NRSE is therefore needed. Such closer international cooperation would aid the transition to an energy future making intensive use of NRSE.

This paper presents the share of renewable energy, especially biomass, in world total energy consumption, and ESCAP's activities in NRSE and intitiatives which will help and provide acceleration of the development and utilisation of NRSE in the Asia-Pacific region.

## 16.2. Share of Renewable Energy in Total Energy Supply

The current share of renewable energy in total world energy consumption is estimated at 17.7 per cent. If large scale hydropower and traditional biomass (fuelwood, animal waste and charcoal) are excluded, the share becomes very small, only 1.6 per cent of the world total (Table 1) (1).

Nevertheless, for the past decade, there has been an increase in the development and utilisation of NRSE. In the developing countries, successful government efforts and private initiatives have shown that renewable energy is a viable, and in some cases, completely user-financed, alternative for rural areas without access to electricity (2).

*Table 1: Estimates of the contribution of renewable sources of energy in 1990*

(Million tons of oil equivalent)

| Energy Resource | 1990 |
|---|---|
| Large hydro | 465 |
| Mini-hydro | 18 |
| Geothermal | 12 |
| Solar | 12 |
| Wind | 1 |
| Modern biomass | 121 |
| Traditional biomass | 930 |
| Total renewables | 1559 |
| Total energy1 | 8808 |
| Renewable share of total energy (percentage) | 17.7 |
| Emerging* renewable as percentage of total energy | 1.6 |

Source: Report of the Committee on New and Renewable Sources of Energy and on Energy for Development. First session, 7-18 February 1994, New York, (ref.1)

* Emerging - total renewable minus hydro and traditional biomass

## 16.3. Biomass Energy

Biomass provides about 15 percent of the energy used worldwide, and 38 percent of energy use in developing countries (4-5). Biomass is the principal source of energy in rural areas (4-5). But experience over the past one and a half decades in the ESCAP region has shown that biomass resources are unlikely to complete with conventional sources of energy in meeting expanded rural needs for energy (5-9).

In the ESCAP region, research and development activities, involving various aspects of biomass production, conversion and energy use, have increased over the past 10 years. A major achievement in the biomass technology is the densification of biomass, which involves the use of some form of mechanical pressure to reduce the volume of vegetable matter and its conversion to a solid form which is easier to handle and store than the original material. The application of densification technology to agricultural residues appears to have an important role to play in the reduction of deforestation. Densified fuels based on agro-industrial residues can be used as a substitute for woodfuel in small scale industries and for cooking in households.

## 16.4. ESCAP's NRSE Activities

### Regional Cooperation

For a sustainable supply of NRSE to all sectors of economic development, it is fundamental that NRSE activities undertaken by various national institutions be adequately coordinated arrangements. To address this issue, ESCAP aims to promote intercountry cooperation in the field of NRSE and in rural energy planning through the concept of regional working groups. The objective of the regional working group is to foster self-sustained intercountry cooperative initiatives. A cooperative arrangement amongst the countries of the region in terms of subject-specific working groups in different areas of NRSE, including rural energy planning, is viewed as a viable approach to collectively address issues of sustainable NRSE development.

ESCAP has coordinated and assisted the countries of the region in the establishment of:

- Regional working group on wind energy development and utilisation -- the secretariat is based in China
- Regional working group of geothermal energy development and utilization -- the secretariat is based in the Philippines
- Regional working group on rural energy planning and development -- the secretariat is based in China (now REED under the new UNDP/ESCAP intercountry programme PACE-E)
- Regional network on small hydro power, based in China, already exists and functioning since 1982 (continued under PACE- E).

ESCAP is endeavoring to establish regional working groups in the remaining areas of NRSE.

Through the coordination of ESCAP and the Regional Working Group on Wind Energy Development and Utilization, intercountry cooperation in the application of small scale wind energy conversion systems is being implemented among China, Sri Lanka and Vietnam in a TCDC/ECDC context.

Similarly, joint activities in the field of geothermal energy are being planned for China, Philippines and Vietnam under the coordination of the Regional Working Group on Geothermal Energy Development and Utilisation and ESCAP. Consultation with China is underway to hold a regional expert group meeting on geothermal energy in Kunming in 1996, which would focus on formulating regional cooperation activities based on resource endowments and the requirements of participant countries.

**Commercialization**

Commercialisation is a key factor in the wider diffusion of NRSE technologies. Commercialization initiatives must be based on achieving sustainability through market forces. Efforts should therefore be devoted to commercialization, as well as all marketing aspects of NRSE technologies. Towards this end, ESCAP has been undertaking activities which will help to identify the appropriate niches for applications of NRSE technologies, and improve the existing inadequate linkage between research institutions of NRSE. A current activity on wind energy between China, Sri Lanka and Vietnam is enabling the commercialisation of small wind machines in such markets as salt production and rural electrification in the three countries. Demand analysis and market research on small scale wind energy in the above three countries have also been scheduled for implementation in 1994-95.

With the aim to facilitate the linkage between research institutions-industry-end users, ESCAP is currently planning to stage an energy exhibition in conjunction with a conference on NRSE, APRES'95 (Asia-Pacific Renewable Energy Symposium '95), scheduled for July 1995 in Australia. The project of APRES'95 is conceived on the success of a similar event, Asia Energy'91, held in

Bangkok in 1991. Asia Energy'91 provided opportunity for regional governments to re-evaluate their varied national experiences on the implementation of NRSE for the past decade after the Nairobi Programme of Action in 1981. The aim of APRES'95 is to debate (i) regional cooperation on, and (ii) commercialisation of new and renewable sources of energy in the ESCAP region. This debate will aid the national governments to adjust their expectations for the timing and size of each renewable energy sources' contribution to supplies, so that development priorities can be adjusted, and realistic long-term efforts can be maintained for eventual success.

**Technology Transfer**

Although most of the developing countries of the region have the potential for development of new and renewable sources of energy, such as solar energy, wind energy, ocean energy, biogas and fuelwood, they generally lack the technical and financial capabilities needed for their realisation. Continuous and systematic cooperation for research and development and application of technologies between developed and developing countries and among developing countries is needed.

In order to facilitate the smoother transfer of new and renewable source to energy technologies and their adaptations, it is necessary for the developing countries of the region to improve their technology levels so that they can catch up with developed countries where new technologies have mainly been developed. Research and development conducted cooperatively among the developed and developing countries should foster improvement of their technological capability. Towards this end, activities in the solar PV, geothermal energy and small hydropower areas are being planned for implementation between developed and developing countries for 1994-1995.

**Manpower Training**

ESCAP's NRSE programmes place particular emphasis on training a large number of technicians who are integrated into rural life especially in the remote rural areas that are untouched by conventional approaches, since the application of the appropriate NRSE technologies will require substantial manpower with suitable skills and qualifications. Efforts have been concentrated on ensuring the training of adequate manpower through "training-of-trainers" in roving in-country training courses, so as to ensure the penetration of these technologies as they become available. For effective human resources development and management in remote rural areas the PARS approach has been followed and will be continued. (PARS = Participatory Action Research Systems, pioneered by a team from the Chulalongkorn University, Thailand, East-West Centre, USA and FAO, and successfully applied in the ESCAP rural energy programme).

As a result of the in-country training course on wind energy technology conducted in Vietnam in April 1994, wind energy technology is now being introduced by trained technicians to remote rural areas for rural electrification, and components of wind turbines are being locally manufactured in cooperation with China on ECDC basis. A similar wind energy in-country training course is being planned for Sri Lanka for 1994-95 to use wind energy for salt production along the coastal areas. A training course on solar PV for water pumping for the Pacific countries in 1995 is also in the pipeline.

**Environmental Studies**

The scale of the likely environmental impact of NRSE will depend on the contribution that the technologies are expected to make, and on whether dispersed or centralized systems are adopted. In general, NRSE are often considered to be environmentally benign when compared with most conventional energy sources. ESCAP in cooperation with China, Sri Lanka and Vietnam, is conducting a study on the environmental impacts of wind energy, and the "avoided" emissions due to the use of wind energy. Netherlands will be invited to participate in this activity in light of their long experience in wind energy.

**Integrated Rural Energy Planning**

Sustained rural energy supply remains a central issue in the developing countries of the ESCAP region. A major issue in rural energy planning is an appropriate approach to develop and utilize NRSE to enhance rural energy supplies. For wider dissemination of NRSE technologies, an integrated approach should be followed. NRSE programmes must always be formulated within the context of overall energy sector planning. One way to achieve this is to link NRSE activities with broader and more urgent development issues such as rural development.

Following the integrated approach, ESCAP is implementing a rural energy project, termed Rural Energy and Environmental Development (REED), as part of a UNDP-funded project PACE-E. The REED project is evaluating the effectiveness of the implementation of the "Integrated Approach to Energy Planning for Sustainable Rural Development" by the regional countries (pioneered by FAO) with the incorporation of environmental issues. A workshop has been organised in Beijing, in September 1994 to review the results so far and to identify training needs. The workshop considered human resources development through skill enhancement in the areas of training in NRSE technologies, capacity building, market and entrepreneurial development, as crucial to implementing rural energy planning projects.

## 16.5. Conclusions

Despite some limitations for development that new and renewable sources of energy have been experiencing, the technological and economic progress over the past decade suggests that new and renewable sources of energy have the potential to make a substantial contribution to future energy requirements, especially in the rural areas.

Sustained rural energy supplies remain a major issue in developing countries of the ESCAP region where the vast majority of people live in rural areas. New and renewable sources of energy are crucial for sustaining rural energy supplies. Appropriate methods and technologies to develop and harness new and renewable sources of energy in an efficient manner remain a major concern. Since continuous deforestation is causing serious degradation of the environment, appropriate measures should be adopted to solve this problem.

Rural energy issues will remain a priority in the medium and long term plans of the ESCAP secretariat. Under the current biennial work programme on energy, activities under the Regional Working Group on Rural Energy Planning and Development, and the Regional Working Groups on Wind and Geothermal Energy Development and Utilization are being implemented. In these activities, concerted promotional efforts among the countries of the region are being emphasized and environmental concerns and human resources development issues are being addressed.

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# 17. PETROLEUM COKE BRIQUETTING

*U. Tin Myint, Myanmar*

In Myanmar, the populace use wood and wood charcoal as fuel for cooking. Because of the increasing demand for these fuels, there is a trend towards the gradual depletion of the country's forests. To prevent such a trend from continuing, the Myanmar Government has set up a plan to introduce alternative fuels by carrying out the research and development at the national level.

With the directive of Ministry of Energy and the guidance of Myanmar Petrochemical Enterprise, the Quality Control and Research Department of No.(1). Refinery, Thanlyin, has implemented a project to recycle refinery wastes to be used as alternative fuels.

In the refinery, there is a cooking unit, producing petroleum coke for export, and for local industries as fuel. During the decoking process, loading, unloading, and transportation, a considerable amount of fine coke dust is lost in the coke yard. This dust (waste) can be processed into a domestic fuel, by applying appropriate combustion engineering techniques. The net caloric content of the coke dust, however, is very high and not compatible with the domestic energy requirement for cooking. Therefore some biomass needs to be added to reduce the caloric content to the required level. In Myanmar, many different kinds of biomass are available, namely 1) paddy husk, 2) saw dust, 3) ground nut shell, 4) sesame stalk, 5) straw 6) grass, etc.

A briquetting process using petroleum coke and biomass has been initiated on a laboratory scale. The coke powder (20 mesh), saw dust, filler, and starch were mixed and made into a paste. The paste was moulded manually into a hollow cylindrical form (2 inches long) and dried under the sun for two days. The briquette was burnt in an ordinary charcoal stove and the performance was checked. It was found that the ignition was poor with unburned residues. Through process modifications, the optimum results (easy ignition, uniform burning, a little unburned residue, less ash and air pollution free) were finally achieved.

To carry out the operation at manufacturing scale, a shift from a manual to a mechanical briquetting process was implemented by introducing a screw extruder of capacity 20 kg/hr.

The difficulties encountered in our petroleum coke briquette manufacturing process are:

- generation of smoke on ignition of briquette
- the design of the extruder
- shapeless briquettes.

We are now distributing the petroleum coke briquette to the general public to substitute for wood and charcoal, with proper instructions for the effective use of this fuel. The demand is rising and we hope that future prospects are promising. Finally, I would like to state that the provision of any assistance from FAO to promote technical know-how and appropriate equipment to produce various kinds of briquette made from the raw materials available in Myanmar would be greatly appreciated.

# 18. COUNTRY REPORT THE UNION OF MYANMAR

*Mr. Ngwe Soe, Myanmar*

## 18.1. Energy Production

Energy production by sources for the year 1992-93 is given in Table 1.

*Table 1. Primary energy supply in 1992-93*

| Source | Gross Supply (Thousand TOE) | Percent |
|---|---|---|
| Oil | 934.9 | 7.60 |
| Gas | 911.5 | 7.41 |
| Coal | 61.5 | 0.50 |
| Hydropower | 412.1 | 3.35 |
| Biomass | 9981.1 | 81.14 |
| TOTAL | 12301.1 | 100.00 |

| | |
|---|---|
| Total energy production in thousand BOE: | 70439.80 |
| Population (in million): | 42.33 |
| Per Capita Consumption in BOE: | 67.00 |

It can be observed that 81% of the energy production came from biomass, with natural gas supplying 7.4%, oil 7.6%, hydropower 3.3% and coal 0.5% only. It is noteworthy that biomass is by far the country's major source of energy supply.

## 18.2. Energy Consumption

The final energy demand by sector in 1990 is given in Table 2.

*Table 2. Final energy consumption by sector in 1990*

(Thousand TOE)

| | Household | Transport | Industry | Others | Total | Percent |
|---|---|---|---|---|---|---|
| Fuelwood | 7181.5 | 0.0 | 0.0 | 0.0 | 7181.5 | 78.27% |
| Charcoal | 535.6 | 0.0 | 0.0 | 0.0 | 535.6 | 5.84% |
| Biomass residue | 227.8 | 0.0 | 75.9 | 0.0 | 303.7 | 3.31% |
| Petroleum products | 7.3 | 362.5 | 134.0 | 109.8 | 613.6 | 6.69% |
| Gas | 0.0 | 0.0 | 194.6 | 167.1 | 361.7 | 3.94% |
| Coal | 0.0 | 0.0 | 23.6 | 0.0 | 23.6 | 0.26% |
| Electricity | 48.3 | 0.0 | 88.1 | 19.5 | 155.9 | 1.70% |
| Total | 8000.5 | 362.5 | 516.2 | 296.4 | 9175.6 | 100% |
| Percent | 87.19% | 3.95% | 5.63% | 3.23% | 100% | |

Source: World Bank (1991) Report

It can be observed that the household sector dominates energy consumption with an estimate of 87.2%, industry with 5.6%, transport 4% and other uses 3.2%. Again consumption of fuelwood accounted for 78.3% and that of charcoal 5.8%; the two together accounted for 84.1%. These figures point to the important roles of fuelwood and the forestry sector in the country. Unless other fuelwood substitutes can be introduced, this trend will continue, thus endangering the country's forests and the environment.

## 18.3. Wood Energy Status

Fuelwood and charcoal production in the years 1992-93 and 1993-94 are given in Table 3 together with the forecasts for the years 1994-95 and 1995-96.

*Table 3. Fuelwood and charcoal production, 1992-1996*

| Period / Fuel | 1992-92 | 1993-94 | 1994-95** | 1995-96** |
|---|---|---|---|---|
| | (Tons of 50 cu.ft) | | | |
| 1. Fuelwood | 474,600 | 424,900 | 460,000 | 460,000 |
| 2. Charcoal | 772,670 | 394,658 | 749,500 | 749,500 |

** Forecast figures

The above production data is based on an assessment of royalties, and could be higher as some figures may not be accounted for especially in rural areas. Eighty three percent of the 43 million population is estimated to live in rural areas and the remaining 17% in urban areas. It is rather evident that the consumption of traditional woodfuel is mainly in the rural areas, where it is chiefly used for household cooking purposes. Electricity is limited to the urban areas. Tables 4 and 5 shown below list the areas which had (1990) or are projected to have (2005) severe shortages of fuelwood. Such areas require the urgent establishment of fuelwood plantations.

*Table 4. Fuelwood deficiency status of selected areas in Myanmar (Year 1990)*

(Million air dry tons)

| Deficiency status | State and division | Annual supply | Annual consumption | Deficit |
|---|---|---|---|---|
| I | Ayeyarwady | 1.26 | 3.99 | 2.73 |
| II | Mandalay | 1.28 | 3.79 | 2.51 |
| III | Yangon | 0.40 | 2.70 | 2.30 |
| IV | Sagaing | 1.77 | 3.19 | 1.42 |
| V | Magway | 1.73 | 2.64 | 0.91 |
| VI | Mon | 0.44 | 1.35 | 0.91 |

*Table 5. Projected fuelwood deficiency status of selected areas in Myanmar (Year 2005)*

| Deficiency status | State and division | Annual supply | Annual consumption | Deficit |
|---|---|---|---|---|
| I | Ayeyarwady | 0.59 | 4.71 | 4.12 |
| II | Yangon | 0.21 | 4.30 | 4.49 |
| III | Mandalay | 0.96 | 4.74 | 3.78 |
| IV | Magway | 0.06 | 3.34 | 3.28 |
| V | Sagaing | 1.42 | 3.95 | 2.53 |
| VI | Mon | 0.38 | 1.59 | 1.21 |
| VII | Bago | 3.05 | 3.85 | 0.80 |
| VIII | Shan | 3.63 | 3.75 | 0.12 |
| | Total | 10.30 | 30.23 | 19.53 |

In response to the fuelwood deficit in the Dry Zone Area, Myanmar received US$ two million from UNDP for implementing two-year Fuelwood Plantation Project in Mandalay and Magway Division, commencing 1994.

In order to meet the demand for charcoal in Yangon City, about 0.4 million cubic ton of charcoal, that is equivalent to 1.6 million cubic ton of fuelwood, have to be extracted yearly from the delta area mangrove forests of Ayeyarwady Division. The UNDP granted US$ 0.35 million for a Pilot Project of Rehabilitation, Conservation and Management of the Delta Mangroves. At present, a subsequent and more comprehensive Project of Rehabilitation, Conservation and Management of the Delta Mangroves is being implemented. This commenced in January, 1994 with a grant of US$ 2 million from UNDP.

## 18.4. Fuelwood Crisis

In Maynmar the foremost fuelwood deficit areas are located in the Central Arid Zone. This situation will worsen at the end of the present decade. Fuelwood consumption in the Arid Zone in the year 2000 is projected to rise to 11 million adt, i.e, 7.6 million adt, above the sustained yield level. At the same time, increased deforestation and land degradation will cause widespread environmental deterioration. The government, therefore, has laid down a plan to supply the local needs of fuelwood and to 'green' this area by implementing "The Regreening Project for the Nine Critical Districts of the Arid Zone of Central Maynmar,totaling 51,300 acres as shown in Table 6.

*Table 6. Works plan and budget required*

(acres)

| District | 1994-95 | 1995-96 | 1996-97 | Grand Total |
|---|---|---|---|---|
| **Sagaing District** | 2300 | 2750 | 3200 | 8250 |
| Monywa | 1700 | 2000 | 2300 | 6000 |
| Sagaing | 600 | 750 | 900 | 2250 |
| **Mandalay District** | 5900 | 6100 | 6300 | 18300 |
| Myingyan | 3700 | 3900 | 3900 | 11500 |
| Meiktila | 1500 | 1500 | 1700 | 4700 |
| Yamethin | 700 | 700 | 700 | 2100 |
| **Magway District** | 7050 | 8300 | 9400 | 24750 |
| Pakokku | 1200 | 1450 | 1700 | 4350 |
| Minbu | 1000 | 1250 | 1600 | 3850 |
| Magway | 3100 | 3500 | 3700 | 10300 |
| Thayet | 1750 | 2100 | 2400 | 6250 |
| **Grand Total** | 15250 | 17150 | 18900 | 51300 |
| Total cost (Kyat in Thousands) | 30500 | 34300 | 37800 | 102600 |

Cost per acre: Calculated at the rate of kyats, 2000.
Total budget required for the project period: Kyats (102.6) million.

## 18.5. Residue from Saw Milling

At present, due to the inefficiency of most saw mills, the average percentage of wood residue including bagasse and sawdust is as high as 64% for teak and 55% for hardwood as shown in Table 7. It can be observed that this residue could be used as a major raw material for large scale briquetting production.

*Table 7. Wood Residue Percentage in Saw Milling*

(Cubic Metres)

| Year | Particular | Throughput | Outturn | Residue | Residue (%) |
|---|---|---|---|---|---|
| 1989-90 | Teak<br>Hardwood | 290865<br>460880 | 96367<br>189077 | 194498<br>271803 | 66.87<br>58.97 |
| 1990-91 | Teak<br>Hardwood | 231432<br>405464 | 76907<br>168056 | 154525<br>237408 | 66.77<br>58.55 |
| 1991-92 | Teak<br>Hardwood | 245140<br>402747 | 104969<br>216688 | 140171<br>186059 | 57.18<br>46.20 |
| Average | Teak<br>Hardwood | 255812<br>423030 | 92748<br>191274 | 163065<br>231757 | 63.74<br>54.78 |

## 18.6. National Implementation of Fuelwood and Charcoal Substitution Programme

To reduce the pressure of fuelwood and charcoal production on natural forests, the government has designated 1995 as "The Year of Substitution Use of Fuel by other Possible Means". "The Innovation and Application of Fuelwood Substitutional Fuel Working Central Committee" has been organised and educational seminars, workshops, demonstrations and training programmes are being conducted throughout the country. The government is encouraging and giving all necessary support to state-run and private organisations which have a keen interest in producing biomass briquettes.

# 19. PERFORMANCE APPRAISAL OF BRIQUETTING PLANTS IN INDIA

*A.K.Khater and S.K.Choraria, Faridabad, India*

## 19.1. Overview of Plants in India

India produced about 0.1 million tons of fuel briquette during 1994-95. This production level is insignificant if we have to achieve production level of 3.5 MT by the turn of the century.

Briquetting plants have been established in India on a commercial for more than a decade but the performance of the plants established during the earlier years were unsatisfactory for basis the following reasons:

- Imported presses installed during the initial years could not briquette unground agricultural residue satisfactorily, because of high abrasion, low bulk density and high moisture content.

- Similarly, briquetting presses manufactured in India also failed and most of the plants could not commercially viable and had to close down.

However, enterprising efforts to establish briquetting technology for Indian raw material continued and by designing preprocessing equipment utilisation of the briquetting press was improved. Preprocessing activities have contributed significantly to increasing utilisation. Such activities include: the use of a flash dryer for saw dust and similar material which has ensured continuous operation of plant; grinding of shell and stalk which has increased the bulk density considerably, has led to the output from the presses being improved significantly and, it has also resulted in decreasing the abrasion on pressing tools; blending of materials of different type has ensured continuous running of plants. Recent experiments of heating the biomass before pressing may result in a substantial increase in output and marked reduction in power consumption. Nevertheless, more research and development has to be done to increase the efficiency of preprocessing equipment. In view of the above, performance appraisal of operating plants is desirable and the following annexures will demonstrate the present state of most of the plants.

**ANNEXURE-I**

## Capacity Utilisation and Constraints in Production

| Description of plant | Capacity installation | Plant supplied by | Utilisation | Financed by | Remarks |
|---|---|---|---|---|---|
| **A. GOOD OPERATING PLANT** | | | | | |
| Anand Khandsari | 3000 kg/hr | SSC/New Life | 85% | Self | Production low during rainy season |
| Nitin Biocoal | 1000 kg/hr | SSC/New Life | 80% | Self | Power disturbance |
| Gayatri Biocoal | 1000 kg/hr | SSC/New Life | 70% | IREDA | Power restriction |
| Devi Renewable | 1500 kg/hr | Ameteep | 70% | IREDA | Power restriction |
| Punjabi Agro | 1250 kg/hr | SSC/Hi-Tech | 70% | Commer. bank | New plant |
| Vikram Agro | 750 kg/hr | SSC/New Life | 70% | Commer. bank | New Plant |
| Hariom | 1250 kg/hr | SSC/Hi-Tech | 80% | MSFC | New plant |
| **B. AVERAGE OPERATING PLANT** | | | | | |
| Witco | 500 kg/hr | SSC | 60% | IREDA | Utilisation low due to break down |
| Vijay Industries | 1250 kg/hr | SSC/New Life | 65% | Self | Power restriction |
| Jindal Briquette | 500 kg/hr | SSC/Triad | 65% | Self | Material mix |
| Darshan Singh | -- | Local | 65% | GSFC | -- |
| Nemi Briquette | -- | SSC/New Life | 60% | GSFC | Low motivation |
| **C. PLANT OPERATING BELOW AVERAGE (LESS THAN 50%)** | | | | | |
| Mohta Agro | 3000 kg/hr | Imported Alternate | | UPFC | Problem in marketing |
| Indoden | 7000 kg/hr | ISGEC-2 press Alternate-2 press | | IREDA | Problem in marketing |
| Agri Carb | 2500 kg/hr | Alternate-1 press SSC-1 press | | IREDA | Defective pre-processing equipment |
| Majha Energy | 1600 kg/hr | SSC/New Life | | PFC | Shortage of raw material |
| Punjab Hydro Carbon | 1000 kg/hr | SSC/New Life | | PFC | Shortage of raw material |
| Gurukripa | 1000 kg/hr | SSC/New Life | | IREDA | Shortage of raw material |
| PAB Fuels | 1000 kg/hr | SSC/Triad | | IREDA | Shortage of raw material |
| Abohar Biocoal | 1000 kg/hr | SSC/New Life | | IREDA | Shortage of raw material |

**ANNEXURE-II**

## Manufacturing Cost and Raw Material Mix

| Item | Cost | Operating life | Cost Rs/ton (including repair) |
|---|---|---|---|
| Ram | Rs. 1350/- | 80-200 Hrs<br>Total 600 to<br>1200 hrs after repair | 2.50-6.00 |
| Taper die | Rs. 1600/- | 200-500 hrs | 3.00-8.00 |
| Split die | Rs. 1200/- | 200-500 hrs | 2.50-6.00 |
| Wear ring | Rs. 300/- | 40-100 hrs | 3.00-7.50 |
| Total | | | 11.00-28.50 |
| Lubricating oil | Rs. 50/- | Old m/c 0.5 ltr/hr<br>New m/c 0.1 ltr/hr | 25.00<br>5.00 |
| Power | | Consumption per ton | |
| Briquetting<br>Drying<br>Grinding | | 30-40 kWh<br>8-10 kWh<br>15-20 kWh | |
| | | 53-70 kwh | 120-160 |

**ANNEXURE-III**

## Major Indicators for Good Operating Plant

- Raw Material Mix - There should be a minimum of three raw materials and none of them should be soft with high lignin or oil content.
- Raw Material Storage - Stock of material should be around 3 months of production capacity to maintain desired mix in the lean season.
- Briquetting Press - Presses should be in a position to work for 20 hours in a day and six days a week without heating.
- Pre-Processing Equipment - (i) Efficient drying is essential, (ii) Proper grinding to achieve desired bulk density is necessary, (iii) Heating of biomass may also increase the production and reduce the costs of power and wear of parts.
- Reliable and Adequate Power Supply - Continuous working of plant is desirable to increase the output and reduce the wear cost. It is said that most breakdowns take place during plant start up.

## 19.2. Present Manufacturing Practices of Briquetting Machines

Most of the machines manufactured in India are similar in construction to Fred Hausman Machines model FH60/150. Imported in the early eighties this design has long been discarded by the original developer. This model is characterised by (i) built-up crakshaft made of a straight shaft with a separable eccentric mounted on it and (ii) a crosshead which comes out of the press when it is working. Most of the breakdowns of these machines may be attributed to these features. The oil coated surface of the crosshead, exposed to the atmosphere catches the dust present in the surrounding space and takes it inside the body chamber. The dust goes into the lubricating system and chokes the thin oil lines, stopping the supply of oil flow to one or other of the bearing bushes and causes a breakdown. The built-up crankshaft with its large crank diameter makes replacement of crank bush and restoration of the original condition beyond the ability of the user. Furthermore, the replacement of costly teflon seals on the crosshead surface which wear out in a week or two and cost over Rs 800/- per set, is a costly proposition and is usually not done in time. As a result there is oil leakage outside necessitating frequent replenishment and dirt keeps on mixing with the lubricating oil, making it less and less effective. The solution to these problems was an integral crankshaft (with reduced diameter) and a totally sealed crosshead (Fig.1). In the new design the ram comes out of the press instead. The ram is dry, replaceable and can stand a harder and more effective seal. Replacement of the two piece crank and shaft assembly by a single piece crankshaft in the new design has resulted in substantially lower power consumption, longer lubricating life and ease of maintenance. Frequent breakdown due to connecting link bush and feeder box related accidents are now a thing of past. Briquetting presses, model P62175/P6175 which represents state of art technology, are manufactured at a well equipped factory with twenty years experience. Grade I tolerances are achieved and ram to wear ring concentricity is within 0.05 mm.

**Salient Features of Press: Model P6200/P6175**

- Wider and longer body, increased bearing surfaces.
- Longer stroke and increased production.
- Body stress relieved and precision bored for longer life of wear tools.
- Water cooling of machine headstock for 24 hours working.
- Integral crankshaft removes the possibility of misallignment
- Case hardened and ground alloy steel crankshaft and crosshead.
- Effective separation of oil and dust areas by covering crosshead.
- Pressure lubricated bronze bush bearings.
- Easy replacement of crank bush.
- Easier die holder mounting.
- Support of die holder during mounting.
- Flywheel balanced in assembly.
- Automatic stoppage of feed on overload.
- Automatic stoppage of press on low pressure.
- Regulated oil supply to different lines.

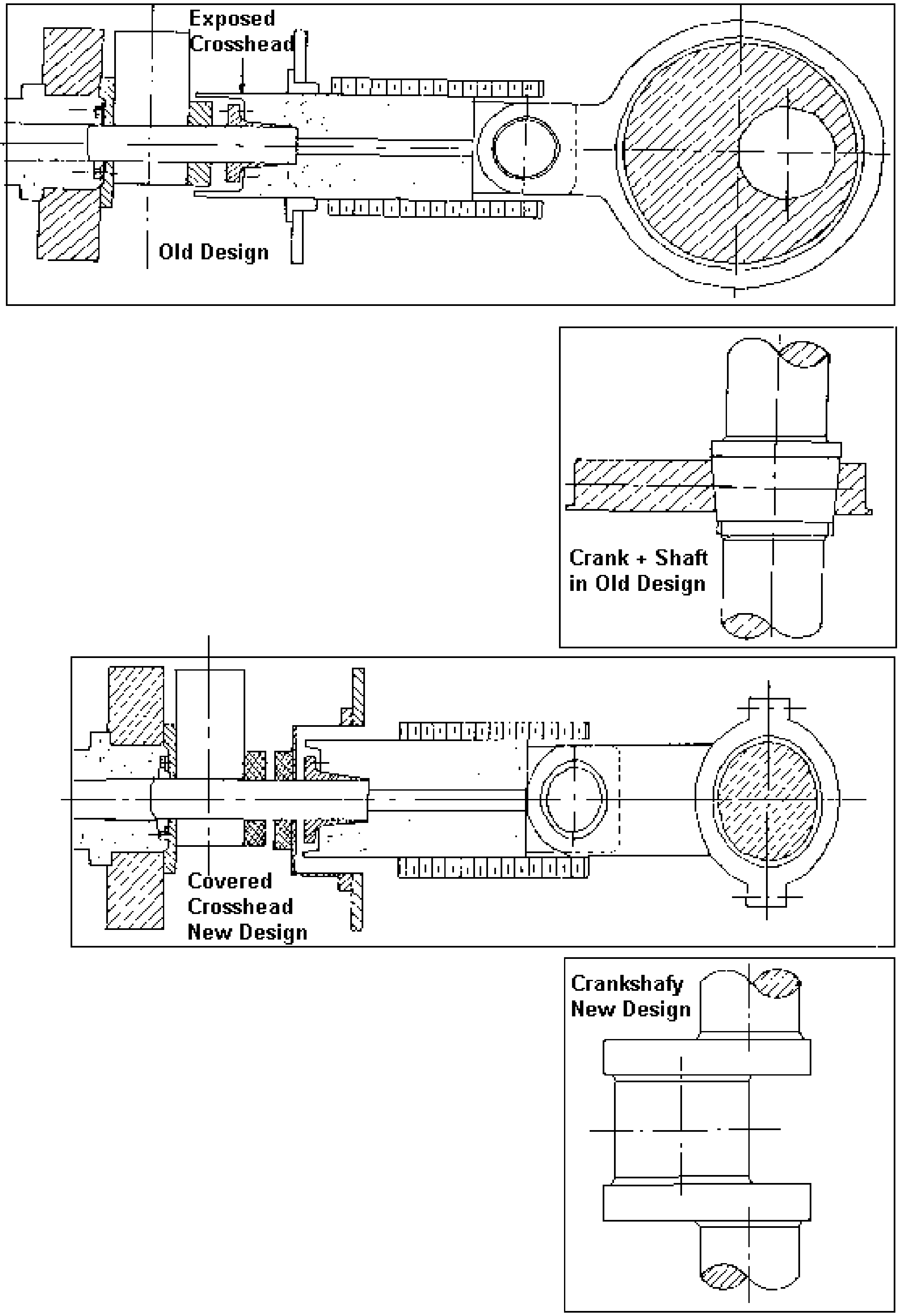


*Fig.1 Old and new model piston presses.*

# 20. COMPARATIVE COMBUSTION CHARACTERISTICS OF BIOMASS BRIQUETTES

*V.Bansal, P.D.Grover and S.K.Mishra, IIT, Delhi, India*

## 20.1. Introduction

Coal and wood are predominantly used in India for combustion purposes. A major effort is underway to replace these by agro-residues, a major component of bio-residues, which are used in efficiently in their original form. Agro-residues are usually burnt loose causing pollution to the environment and, moreover, the ash contains a large proportion of unburnt carbon due to incomplete combustion. A major disadvantage of agricultural residues as a fuel is their low bulk density, which makes handling difficult, and transport and storage expensive. However, agro-residues in their compact form, i.e. briquettes obtained by different densification technologies can be used for their better utilisation and improved efficiency. Briquettes show better combustion characteristics and also can be handled easily.

There are two main technologies used for briquetting purposes: 1. Piston press and 2. Screw press.

Piston press briquettes (ram and die principle) are circular and solid in shape. The piston press is widely used in India. In Europe screw press machines are used for briquetting of swadust. The shape of the briquette is hexagonal with a concentric hole at the centre. Though the density of both type of briquettes is almost same the combustion characteristics are very different.

Several trials have been conducted to determine their combustion performance. Screw press briquettes were found to be more suitable compared to piston press briquettes in every aspect of combustion.

## 20.2. Observations

Various briquettes were burnt in the laboratory using well designed combustion equipment to study briquettes of different materials and shape, with the weight kept identical. Some of the data recorded on burning these briquettes was used to determine lighting time, flaming time, length of the flame, time when flame dies and time for combustion for char (incandescence).

Single briquettes were burnt to test their combustion characteristics. It was found that some of the fixed carbon remained in the ash. This may be due to the fact that only a single briquette was burnt and after some of the portion of the sample is burnt, a part of it does not get the required heat to burn further.

Samples of sawdust, groundnut shell, rice husk, coffee husk, wood were burnt. Solid fuel briquettes in bulk are generally found to burn for 50 minutes in a furnace but because only a single briquette was burnt it lasted for around 90 minutes. The combustion equipment is shown in Fig.1. In each case, 100 ml of industrial grade acetone was used as an igniter.

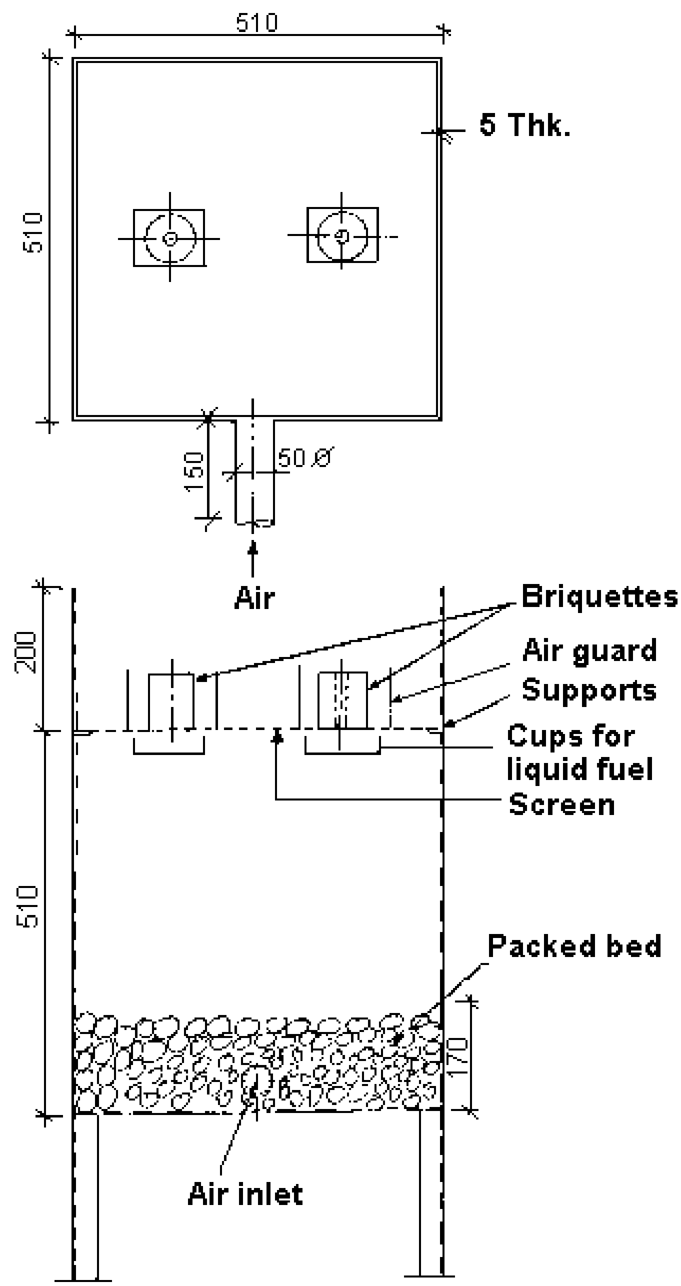


*Fig.1 Equipment to test combustion of briquettes.*

**Groundnut shell (Solid)**

The ignition was found to be difficult and continued to give smoke for about 45 minutes. During this time some of the volatiles also escaped without burning. It then smouldered with a glow (char oxidation) for the next 50 minutes. In the last few minutes fixed carbon content was not adequate and combustion died down. The briquette was found to crumble during combustion.

**Groundnut shell (Hollow)**

A 200 gm briquette was combusted. After initial smouldering of nearly 8 minutes, the briquette started to burn lasting for 15 minutes. The length of the flame was initially 12 cm high and decreased continuously till it died down. Except for a few traces of smoke observed initially, the briquette burnt without smoke. The incandescence lasted for 70 minutes.

**Rice husk briquette (Hollow)**

After the initial period of 8-9 minutes for igniting the briquette, it was found to burn with 14 inches high flame which subsequently lasted for 10 minutes. Then it continued to glow for an hour.

**Sawdust briquette (Hollow)**

The ignition time being same, the flame length was found to be 18 inches high with flame lasting for 10 minutes after which it continued to glow and it lasted for 90 minutes.

**Coffee husk briquette (Hollow)**

Coffee husk in its compact form produced a lot of smoke compared to other briquettes. After about 30 minutes, it lost its dark brown colour and turned into a black charry mass.

**Wood (Solid)**

Wood did not burn properly without drying. After burning with acetone for eight minutes, it burnt with a flame of 15-16 cm length which lasted for about 10 minutes. Then it turned black, continued to glow, crumbled into pieces. Wood also produced smoke while burning.

## 20.3. Discussion

The screw press briquettes are homogenous in nature and therefore the shape is not distorted during combustion. The piston press briquettes get crumbled because they are non-homogenous. The heat penetrates easily at the joints resulting in pyrolysis near the joints. The escaping of volatiles from the joints results in crumbling.

Due to high surface area per unit weight the hollow briquette gets heated from both sides due to which heat penetrates evenly resulting in volatiles escaping at a reasonable rate giving rise to flames. Availability of an adequate supply of air (due to high surface area per unit weight) and supply of volatiles ensures that briquettes burn with a flame and negligible smoke.

In the solid briquette heat is not conducted properly leading to insufficient combustion of volaties resulting in smoke. Screw press briquettes are extruded in a heated die. This ensures that the energy density of the surface is high leading to ease of ignition. The high flame in rice husk and sawdust may be attributed to their low decomposition temperature and also high volatile content. The compact structure also helps to conduct heat better. The combustion of a briquette can be understood in stages. Initial ignition by fuel results in heating and drying subsequently resulting in solid and gas phase pyrolysis which in turn gives a flame. After the volatiles burn out the smouldering with a flame corresponds to char oxidation. The erratic behaviour of coffee husk can be attributed to the fact that coffee tends to devolatilise very quickly such that is not able to oxidise properly, resulting in smoke.

# 21. BIOMASS USED AS ENERGY IN VIETNAM

*Mr. Nguen Duy Thong, Vietnam*

## 21.1. Introduction

Vietnam is a tropical-agricultural country situated in South-East Asia, with a surface area of about 331,200 sq. km. Vietnam is a predominantly rural country, about 80 per cent of the country's population lives in rural areas. National statistics show a total forest area of about 20.0 million ha., equal to about 60 percent of the total land area. Statistical data of the Ministry of Forestry in 1993 indicate that 28.4 percent (9.39 million ha) of the total land is covered by forest of which, 8.63 million ha is natural forest and 0.76 million ha is plantation forest. About 35-40 million cubic metres of round wood and 20-25 million tons of fuelwood and biomass (in fuel wood equivalent) were supplied annually from forest areas. Agricultural land occupies 7.7 million ha or about 23.2 percent of the total land. The principal crop is rice, which accounted for 84 percent of the agricultural land, and 89.7 percent of the total production from food crops (in rice eqivalent) in 1992. Enhanced agricultural production has contributed to improvement in the supply of raw materials to industry and increase in export. At present the energy supply system in Vietnam has made good progress, however, the energy consumption per capita is estimated to be one of the lowest in the world (World Bank report). Biomass, oil, electricity and coal are the main sources of energy in Vietnam. It is important to note that at present non-commercial energy, mainly from biomass fuel, shares a great part of the total energy supply.

Like many other countries, the rural population of Vietnam utilizes biomass such as wood, leaves, grass and agricultural residues as the main source of energy. However, with lack of fuelwood sources (mainly fuelwood from forest) and with the enhancement in the standard of living of the community and improvement in technological capabilities, there has been a change to fossil fuels and electricity. The energy used in the household sector usually comes from fuelwood and agricultural wastes like rice straw, rice husk, maize stalks/cobs, casava trees, sugarcane tops, bagasse, coconut shells and husk etc.

## 21.2. Biomass Potential

The biomass potential is given in Table 1.

*Table 1. Biomass potential in Vietnam*

| No. | Source | Physical tons ( x 1000) | In TOE x 1000 | % |
|---|---|---|---|---|
| 1. | Fuelwood (from natural plantation, degraded forests and wood processing residues etc.) | 44,816 | 16,133 | 57 |
| 2. | Agricultural residues | 30,892 | 10,500 | 37 |
| 3. | Residues of multi-layer industrial crop (tea, coffee, coconut etc.) | 4,679 | 1,690 | 6 |
| | Total | | 28,323 | 100 |

The figures in Table 1 shows that biomass potential in Vietnam is limited. Fuel wood potential takes a dominates, however this source is now rapidly decreasing. Agricultural residues is increasing, but agricultural residues need to be used for other purposes, only 31.3 percent is used for energy. The following shows the pattern of utilization of agro-residues in 1989-90.

| *For Energy* | *For Animal Feed* | *For Fertilizer* | *Others* | *Total* |
|---|---|---|---|---|
| *31.3%* | *21%* | *37.2%* | *9.5%* | *100%* |

## 21.3. Some Constraints of Biomass Supply and Utilization

- ! Biomass energy is generally regarded as a free commodity. Most people in rural areas collect and use biomass energy by themselves to meet their demand without any plan and management. This may cause deforestation and adverse impact to the environment.
- ! The fuelwood shortage has become serious in several regions of the country. However, the usage of biomass energy is still very inefficient. Direct combustion of biomass is the popular and practical method in Vietnam. Traditional stoves with very low efficiency are being used largely especially in rural areas. This is one of the main reasons for the high biomass energy consumption and its negative consequences.
- ! Biomass is a low-value product. It needs a large area for storage, and has a high transport cost.
- ! Different kinds of suitable stoves are needed for each type of biomass fuel.
- ! A lot of smoke, dust, ash come from biomass burning, and it is necessary to take constant care of fire while cooking.

## 21.4. Recommendations

- An inventory should be made of the availability of biomass and other residues for determining and planning their potential for conversion into energy form.
- Further research and development efforts should be undertaken to make biomass energy conversion technologies economically profitable and socially acceptable to the public for their wider acceptance.
- It is also necessary to strengthen the mechanisms for information dissemination and technical guidance to promote biomass conversion technologies.
- Technical cooperation among developing countries should be encouraged and information exchange needs to be promoted through the organisation of training workshops, seminars and study tours on biomass energy conversion technologies in the region.

# 22. TRADITIONAL ENERGY USE AND AVAILABILITY OF AGRICULTURAL AND FOREST RESIDUES

*Mr. Auke Koopmans, FAO/RWEDP, Bangkok*

## 22.1. Introduction

Biomass energy is an important source of energy in most Asian countries. Besides fuelwood and charcoal, substantial quantities of other types of biomass energy such as agricultural residues, dung, leaves, etc. are used for domestic applications such as cooking and heating, but also for small as well as large scale industrial applications. These range from mineral processing (bricks, lime, tiles, ceramics, etc.), food and agro processing, metal processing, textiles(dyeing, etc) to miscellaneous applications like road tarring, tyre retreading, ceremonies, etc.

The FAO-Regional Wood Energy Development Programme or RWEDP, based in Bangkok has prepared an overview of traditional energy use and the availability of agricultural and forest residues for its 15 member countries e.g. Bangladesh, Bhutan, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam.

**Population**

The 15 RWEDP member countries show large variations in size, size of population and energy use. Combined, the 15 countries account for about 51.7% of the world's population which are living on only 13.6% of the total land area. A large part of the population is living in rural areas. However, it is expected that the urban-rural ratio will change. It is anticipated that in the RWEDP countries in the next 20-25 years the ratio of rural to urban population will change from about 73:27 to about 67:33 in the year 2000 and may reach 60:40 in the year 2010. Even though the ratio changes, the absolute rural population will still be rising. Demographic projections published by the World Bank in 1984 suggest a stable total population of around 11 billion by the year 2150 while the rural population is expected to reach its maximum around 2010-2015.

**Energy Use**

According to information contained in World Resources 1994-95 (WRI, 1994), the average per capita energy consumption in Asia including traditional energy sources such as fuelwood, residues, dung, leaves, etc. was about 28.2 GJ in 1991. This is still low when compared to the World's average of 63.4 GJ. The 15 RWEDP member countries, however, show only a per capita total energy consumption of about 18.3 GJ, even lower then the Asian average. Traditional sources of energy are important and can be considered as vital for the rural based industries which provide income for many people in rural areas. Table 1 shows the traditional energy use for RWEDP member countries. Since the supply of commercial sources of energy in the rural sector is unreliable, wood and other biomass fuels are the only large sources of energy which are economically viable and potentially sustainable.

*Table 1. Traditional energy use for RWEDP member countries.*

| Country | Traditional energy use in MTOE | | | | |
|---|---|---|---|---|---|
| | Total | Woodfuels | Residues | Dung | Year |
| Bangladesh | 11.56 | 2.69 | 7.13 | 1.74 | 1989/90 |
| Bhutan | 0.33 | 0.33 | Neg. | -- | 1988 |
| China | 185.70 | 90.16 | 89.13 | -- | 1988 |
| India | 105.11 | 57.07 | 14.41 | 33.63 | 1990 |
| Indonesia | 26.54 | 20.94 | 5.60 | -- | 1992 |
| Laos PDR | -- | 0.79 | -- | -- | 1989 |
| Malaysia | 5.96 | 1.91 | 4.05 | -- | 1990 |
| Maldives | -- | 0.03 | -- | 0.00 | 1989 |
| Myanmar | -- | 6.41 | -- | -- | 1990/91 |
| Nepal | 5.76 | 4.32 | 0.95 | 0.49 | 1992/93 |
| Pakistan | 19.26 | 11.47 | 4.17 | 3.61 | 1991 |
| Philippines | 11.43 | 7.90 | 3.54 | -- | 1989 |
| Sri Lanka | 4.57 | 4.44 | 0.13 | -- | 1990 |
| Thailand | 10.40 | 7.89 | 2.51 | Neg. | 1993 |
| Vietnam | 20.99 | 10.68 | 10.31 | Neg. | 1990 |

## 22.2. The Resource Base and Its Demand

It is true that the traditional sources of energy are important for rural as well as urban areas of the 15 RWEDP member countries. Although no doubt there will be shifts in the use of energy (mainly upgrading, but in some cases downgrading in the use of different types of energy as well), the overall impression appears to be that the use of traditional sources of energy will remain important and most probably will increase in absolute terms. The increased use of energy, be it conventional sources such as oil, gas, electricity and coal or traditional sources of energy such as woodfuels, residues, etc. will put more pressure on the resource base.

In order to be able to judge whether an increased use of traditional fuels will put more pressure on the resources, an overview of the resource base will be given. This will only deal with logging residues as well as residues from wood processing such as sawmilling and the manufacture of plywood and particle board and wood residues generated from crop plantation operations such as pruning, replanting of trees, agricultural residues, etc. It does not include woodfuels obtained directly from trees such as those growing in the forests (clearing of forest lands for agricultural purposes, cutting or lopping trees purely for fuelwood, etc.), trees growing on communal lands, on waste lands, on private land such as home gardens, trees growing along roads, etc. Although in particular the latter e.g. trees growing on non-forest areas are an importnt source of woodfuels and in many cases even more important than woodfuels obtained from the forests, these are not covered here as not enough is known about the resource base. For the same reason dung has not been covered. It should be noted that the information only shows the gross amount of residues which in theory are generated. In practice such an amount is normally not available. This is due to a variety of reasons such as for instance being used as a raw material, used for other non-energy purposes, being non-recoverable, etc. Conversely, residues may be available but there may not be a potential user for such residues.

Residues are used for many purposes and such uses often are site specific. Besides being used as fuel, which can be considered one of the "6F's", residues are also used as Fodder, Fertilizer, Fibre, Feedstock and further uses. Although end-uses for the first 5F's may be obvious, the latter "F" comprises for instance residues being used as a soil conditioner (coconut coir dust used to retain moisture in the soil, straw as a growing medium for mushroom, coconut husks as a growing medium for orchids, packing material, etc. In some cases residues may even have a multi-purpose use: ricehusk can be burned as fuel with the ash being used by the steel industry as a source of carbon and as an insulator. Rice straw can be used as animal bedding and subsequently as part of compost (fertilizer), crop waste can be used as a feedstock for biogas generation (fuel), with the sludge being used as fertilizer, etc.

It is sometimes assumed that residues are wastes and therefore by definition more or less "free". However, in practice it is unwise to assume so. In a monetized economy, even where residues are at present freely available, everything which has a use will sooner rather than later acquire a monetary value. With regard to the present use, a brief overview will be provided here.

**Forest and wood processing residues**

**Logging residues:** Recovery rates vary considerably depending on local conditions. A 50/50 ratio is often found in the literature e.g. for every cubic meter of log removed, a cubic meter of waste remains in the forest (including the less commercial species). Where logging is carried out for export purposes, values of up to 2 cubic meter of residues for every cubic meter of log extracted may be valid (Adams, 1995). Other sources (Forest Master Plan for Indonesia, GOI 1990) give a ratio of 60/40 e.g. 6 cubic meters of logs versus 4 cubic meters of waste remaining in the forests. The 40% consists of: 12% stemwood (above first branch), 13.4% branch wood, 9.4% natural defects, 1.8% stemwood below first branching, 1.3% felling damage, 1.6% stump wood and 0.5% other losses.

Figures of 30% logging wastes have been reported from Malaysia (FRIM, 1992) but others (Jalaluddin et al, 1984) indicate a recovery rate of 66% with 34% being residues, consisting of stumps, branches, leaves, defect logs, offcuts and sawdust. This figure may be higher if unwanted species intentionally or accidentally felled are considered as well. Most of the wood residues are left in the forest to rot, especially in sparsely populated areas where the demand for woodfuels is low. In some cases the residues are processed into charcoal. In order to calculate the amount of logging residues an average recovery factor of 60% has been assumed.

Logging residues consist of branches, leaves, lops, tops, damaged or unwanted stem wood, etc. Such residues are often left in the forests for various reasons of which the low demand for fuel (with a high moisture content) in such areas is probably an important consideration as well as logistics. This is not to suggest that forest-residue recovery is not undertaken. For instance in Sweden there is considerable recovery in the form of woodchips (bulk density about 300 $kg/m^3$) for use in industries as well as domestic purposes. In Bhutan, due to the demand from a calcium carbide industry, logging residues are often converted into carcoal which is then sold to the carbide industry.

**Sawmilling:** Recovery rates vary again with local practices as well as species (FAO, 1990c). After receiving the logs, about 12% goes to waste in the form of bark. Slabs, edgings and trimmings amount to about 34% while sawdust constitutes another 12% of the log input. After kiln drying the wood, further processing may take place resulting in another 8% waste (of log input) in the form of sawdust and trim end (2%) and planer shavings (6%). For calculation purposes a yield factor of 50% has been assumed (38% solid wood waste and 12% sawdust).

Sawmill residues are used for various purposes but much depends on local conditions such as demand centres nearby. Part of the residues are used by the sawmills themselves, basically for steam generation for timber drying purposes. However, the bulk remains unused (AIT, 1994). Where a local demand exists, wood residues are used for various purposes, mainly as a source of energy for brick and lime burning, other small industrial applications as well as a source of raw material such as for parquet making, blockboard, etc. In the north of Thailand sawdust is briquetted and carbonized and sold as a high grade charcoal which commands a higher price than normal charcoal. Considerable quantities are apparently also used for charcoal making as a cover on charcoal mound kilns.

**Plywood production:** Recovery rates vary from about 45-50% with the main variable being the diameter and quality of the log. 7% of the log input becomes waste in the form of log ends and trims, the bark forms another 5%, log cores (10%), green veneer waste (12%), dry veneer waste (8%), trimmings (4%) and rejected plywood (1%) form the largest amount of waste while sanding the plywood sheets results in another loss of 5% in the form of sander dust (FAO, 1990c). For calculation purposes a yield factor of 50% has been assumed with residues consisting of 45% solid wood residues and 5% in the form of dust. However, higher recovery rates have been found in the literature and a figure of 54% has been reported as being the average for Indonesian plywood factories (Weingart et al, 1988).

Within the plywood industry a demand exists for part of the residues. In Malaysia from 30-50% of the residues are used for power and steam generation while in Indonesia about 20% of the plywood mills use their own residues (AIT, 1994). The latter source indicates that in Thailand and the Philippines little of the residues is used internally by the plywood mills themselves. In the case of integrated wood processing factories, part of the residues are used as a raw material in blockboard and particle board production. The same is true for sawmill residues. In Indonesia the use of the cores for fencing, etc. appears to be quite common at least in the Moluccas.

**Particle board production:** During the production process about 17% residues are generated in the form of trimmings. This amount however is recycled. In addition to this about 5% screening fines and about 5% sanding dust is generated as residues which is mainly used as boiler fuel for process steam generation (FAO, 1990c). For calculation purposes a residue factor of 10% has been assumed consisting of screening fines and dust while 17% of the residues are assumed to be recycled.

### Agricultural residues (annual crops)

Agricultural residues constitute a major part of the total annual production of biomass residues and are an important source of energy both for domestic as well as industrial purposes. Even though residues are used as fuel, burning of residues in the field is still a common occurrence.

**Rice straw and rice husk:** RPR (residue to product ratio) values in the range of 0.416 to 3.96 have been cited in various references concerning rice straw. The lowest 0.416 among the RPR values, reported by AIT-EEC (1983) and 0.452 by Bhattacharya et al, (1990) are based on the practice of harvesting rice in parts of Thailand and other South East Asian countries, where only the top portion of the rice stem along with 3-5 leaves is cut, leaving the remainder in the field. Where the rice is cut at about 2" above ground, the RPR becomes 1.757 (m.c. 12.71%) as reported by Bhattacharya et al, 1993. Vimal (1979) indicates a RPR of 1.875 based on Indian experience while in Bangladesh a value of 2.858 has been reported (BEPP, 1985) which however may be valid only for a local variety. For calculation purposes a RPR value of 1.757 has been used which is based on actual measurements in Thailand.

RPR values for rice husk range from 0.2-0.33. For calculation purposes a RPR value of 0.267 (m.c. 2.37%) has been used as reported by Bhattacharya et al, (1993).

In many countries rice straw is burned in the field with the ash used as organic fertilizer. Relatively small quantities are used as animal fodder, animal bedding, as a raw material for paper and board making, as a building material, etc. In some countries like Bangladesh, Vietnam and possibly India and Nepal straw is also widely used as a domestic fuel. Husks are often burnt at the ricemill just to get rid of the husks but in some countries like Thailand they are used extensively for power generation in the large ricemils. It has been estimated that in Thailand about 50-70% of the husks are used by the ricemills themselves. The remaining 30-50% apparently is not used although the brick industry is increasingly using it as a source of energy. In Malaysia, the Philippines and in Indonesia most of the residues remain unused although also here the brick industry is becoming important as an end-user.

**Maize stalk/stalk/husk:** The literature shows widely varying RPR values ranging from 1.0 to 4.328. Values reported by Vimal (1979), AIT-EEC (1983), Barnard et al, (1985) and Desai (1990) are respectively 2.0, 2.3, 2.0-2.3, and 2.08 whereas Massaquoi (1990) and Ryan et al, (1991) report a value ranging from 1.0-2.5. For calculation purposes a RPR value of 2.0 has been assumed (m.c. 15%). Bhattacharya et al, (1993) report an RPR of 0.273 (m.c. 7.53%) which can be assumed to be acceptable since the value was obtained from actual field measurements. A value of 0.2 with an assumed moisture content 11.11% as reported by Vimal (1979) has been used for calculation purposes.

**Other cereals:** RPR values for wheat straw, as reported by different authors, range from 0.7-1.8. The value reported by Bhattacharya et al, (1993), i.e. 1.75 has been used since the moisture content (m.c. 15%) has been indicated. Since reported RPR values for millet, rye, oats and barley do not show wide variations from that of wheat, the same RPR value has been used. An exception is straw from sorghum where Bhattacharya et al, give a RPR value of 1.25 at a moisture content of 15%.

Very little is known about the use of residues from maize, other cereal crops and soybean straw and pods, other than that residues are widely used as a domestic fuel in particular in areas where fuelwood is scarce.

**Cassava stalks:** Cassava is harvested about 12 months after planting. At harvest the plants are first topped before being uprooted. Part of the stalk is retained for replanting while the remainder is discarded. Tops (leaves) and the discarded part are sometimes left in the field and sometimes used as a domestic fuel. Out of the 10-25 tons of stems and leaves per hectare, about 8 tons becomes available as fuel or about 6 tons/ha on a dry basis (Lim, 1986a).

When looking at RPR values, 0.167-2.0 as reported by AIT-EEC (1983), Bhagawan (1990) and Ryan et al, (1991) appears to be the most suitable for Asian conditions. Assuming a yield of about 30-45 tons of tubers per ha this would result in a residue base of about 4-9 tons per hectare.

Part of the tubers are processed into starch flour and are peeled before processing. Peels represent about 2-3% of the weight of the tuber and this would result that about 1 ton of peels (m.c. 50%) are generated per ha. of cassava destined for starch production.

Stalks and tops (in the case of cassava) are sometimes left in the field but more often used as a domestic fuel, in particular the woody part of the residues. Cassava stalks can be used directly and the same is valid for millet stalks and pigeon pea (arhar) stalks. Using such residues as fuel is easy as their size is quite small, and they are easy to transport and burn like wood.

**Groundnut husks/shells/straw:** Barnard et al, (1985) and Ryan et al, (1991) recommended a RPR value of 0.5 whereas Bhattacharya et al, (1993) give a value of 0.477 with a moisture content of 8.2%. The latter value has been used for further calculations.

Barnard et al, (1985), Ryan et al, (1991) and Massaquoi (1990) all give a RPR value of 2.3 for groundnut straw. This value has therefore been used, assuming the moisture content to be 15%.

Groundnut husks, shells and straw residues from the groundnut are used as fuel for domestic purposes but little if any is known about amounts. Part of the groundnuts are sold in the shell and such shells are normally no longer available as fuel.

**Soybeans straw/pods:** Bhattacharya et al, (1993) have reported a RPR value for soybean straw of 2.5 at a moisture content of 15%. The same source as used for soybean straw indicated that the RPR value for the pods is about 1.0 with the same moisture content of 15%.

**Sugarcane:** In comparison to other crops, sugarcane gives a very high dry matter per unit land area. Bagasse and sugarcane tops and leaves are the main residues of which the former is normally used as an energy source for steam generation while the latter is normally used as cattle feed or is burnt in the field.

**Bagasse:** A number of authors including Vimal (1979), Webb (1979), and BEPP(1985) indicate a RPR value ranging from 0.1-0.33 with a corresponding moisture content of 50%. Bhattacharya et al, (1993) give an average value of 0.29 with a similar moisture content and this has been used further for calculation purposes.

**Sugarcane tops/leaves:** Vimal (1979) and AIT-EEC (1983) reported RPR values respectively of 0.1 and 0.125. USAID (1989) reported a RPR value of 0.3 based on actual field experiments in Thailand with the moisture content being 10%. The latter value has been used for calculation purposes.

Bagasse and sugar cane tops and leaves are the main residues of which the former is normally used as an energy source for steam generation while the latter is normally used as cattle feed or is burnt in the field. Most sugar factories burn all the bagasse they generate even at very low efficiencies. This is done to ensure that all bagasse is burned as dry bagasse is known to be a fire hazard. In some countries bagasse is also used as a raw material for the paper and board industry. Increasing the combustion efficiency in the sugar industry could result in the saving of considerable quantities of bagasse which either could be sold to paper factories or used to generate power and heat (co-generation).

**Jute stalk:** BEPP (1985), Kristoferson et al, (1991) and Ryan et al, (1991) give a RPR value of 2.0 for jute stalks while Barnard et al, (1985) and Desai (1990) reported 1.6-2.25 and 1.37 respectively. For calculation purposes a value of 2.0 and a moisture content of 15% has been chosen.

With regard to jute stalks, only the inner part is used after the jute fibres have been removed (after soaking in water). This soaking requires that the jute stalks be dried before they can be used.

**Cotton stalk:** Massaquoi (1990), Kristoferson et al, (1991) and Ryan et al, (1991) gave similar values of 3.5 to 5.0 for the RPR. An average value of 2.755 for the range of 1.767-3.743 as suggested by Bhattacharya et al, (1990) has been selected for calculation purposes with a moisture content of 12%.

Cotton stalks are at present often burned in the field as leaving them there may result in damage to future crops due to diseases, infestation, etc. Part of it is sometimes used as a domestic fuel.

**Amount of residues generated**

By using the data as presented in the earlier sub-chapters in addition to statistical data on forestry, cropping areas, amounts of crop produced, etc. as published in national and international statistics, a calculation can be made of the amount of agricultural residues generated in the various countries. In aggregate, the numbers look very attractive if not staggering. A distinction has been made between residues generated in the field and those generated during processing. The reason for this is that it may be assumed that in the latter case residues probably will be found concentrated which will make its use, for instance as a source of energy, or disposal more easy. In the former case they may be found spread over larger areas and may remain in the field. Examples of residues which often remain in the field are straw, stalks, tops and leaves (sugar cane), etc. In such cases the straw and stalks are often also concentrated but generally in similar quantities.

Fig.1 (amount per capita) provides an overview respectively of agro-based residues and wood residues. It should be noted that a clear distinction between these two main groupings cannot really be made as within the agro-residues several of the residues resemble wood such as for instance cassava stalks, jute sticks, millet stalks etc.

It should be stressed here that large variations in RPR ratios occur and one should be very careful in applying RPR ratios across the board. Using different RPR ratios can have a tremendous influence on the amount of residues apparently generated. For instance, one of the major world crops, rice, generates two main types of residues: rice straw and rice husk. Combined they account for about 900 million tons of residues using the suggested RPR ratio. However, using the highest ratio, the amount would increase to about 1,900 millions tons while in the case of the lowest reported RPR ratio, the amount would drop to about 300 million tons of rice straw and husks.

**Amount of residues used**

As is clear from this chapter, very little is known about the amounts of residues used for various purposes possibly with the exception of the sugar industry. This lack of knowledge is thought to be due to the scattered nature of the residue generation, its seasonality and differences in local situation both with regard to the production and use of residues, competing uses which may have a very localized influence on the availability and price of residues, etc. Besides these factors, there are other factors which play a role but even less is known about these.

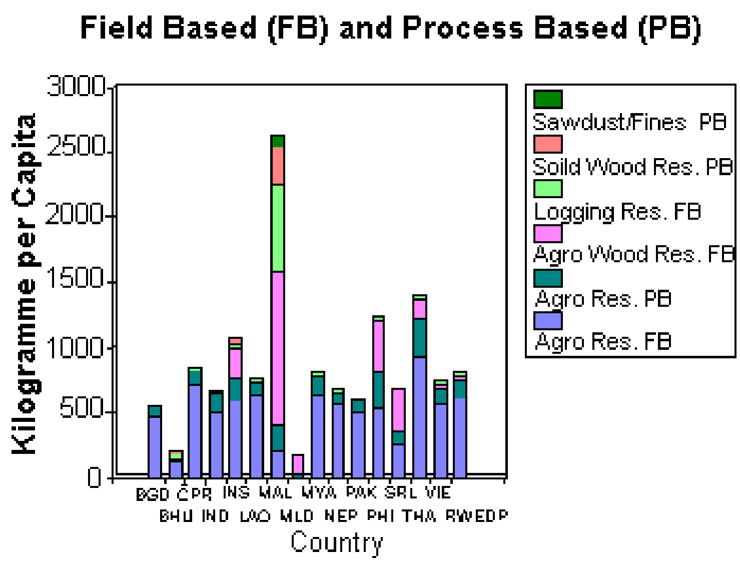


*Fig.1 Amount and type of residues produced in the 15 RWEDP member countries.*

By using the informations available a very rough overview shown in Fig.2 can be made of thye supply/demand situation in the 15 RWEDP countries. It should be noted that for ease of calculation a conversion factor of 3 has been used to convert residues to oil equivalent which implies an across the board valid calorific value of about 14 MJ per kg residues.

However, even though this calculation exercise is interesting in giving a general picture in that it shows that in most countries there still is a considerable amount of residues which apparently are not used, it has to immediately and heavily qualified for any practical assessment of the likelihood that more residues can be used and/or are available. This is also borne out by the fact that Fig.2 shows that in Malaysia more residues are used than generated. This of course can not be true and it is a clear example of the dangers inherent to the system used to calculate the resource base.

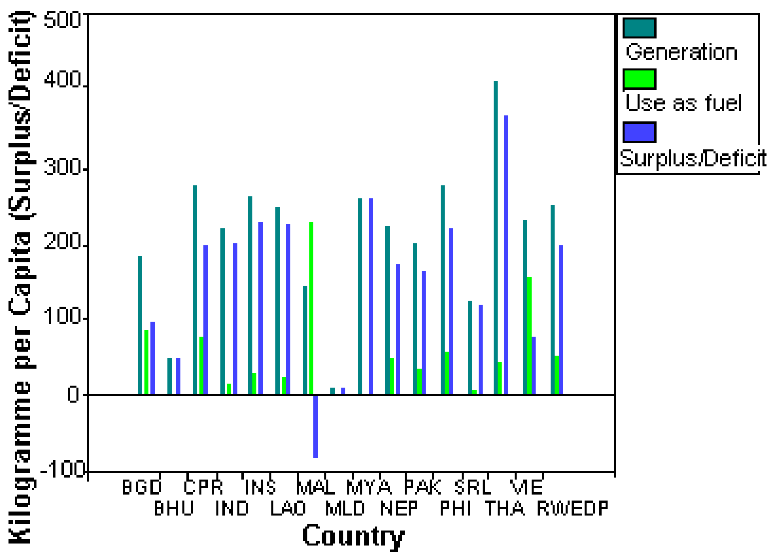


*Fig.2 Agro-residue generation and use (surplus/deficit).*

Besides, it should be noted that the calculation does not take into account any other non-energy use nor of that part of the residues which should be left in the field for environmental considerations. Residues also play an important role in soil fertility and a total removal of all above ground residues could possibly lead to soil degradation. However, the issue of soil fertility and the re-cycling of residues is not well understood. Returning residues to the soil by ploughing them in may play a part in maintaining the quality of the soil by keeping up its organic content. It is also possible that the burning of residues in the fields plays an important role in supplying trace elements. While burning the residues in the field is simple and easy to do, ploughing un-composted residues into the soil is no easy matter. As is the case with residue generation and use, it is here also clear that no generalisation can be made on the effect which increased use of residues will have on soil condition. The importance of any one of these factors will depend largely upon specific local conditions. The problem is compounded by the fact that there is likely to be very little local knowledge about what impact a sudden change in residue recycling patterns would have on the soil. In principle, monitoring of agricultural yields after the change should indicate whether any adverse effects have taken place. R&D of this type, however, would be extremely time consuming, complex and expensive while changes which may occur would be difficult to detect as over time agricultural practices may change and in turn could affect the situation.

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# 23. RAM TECHNOLOGY - PROBLEMS AND SOLUTION

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## 23.1. Constitution of Technical Back-up Cell

IREDA has funded a Technical Back-up Cell under the School of Energy, Bharathidasan University, Tiruchirappalli to study the technical and operational problems of biomass briquetting plants which they fund. In the past year it has developed some proven solutions for some of the major problems of the punch and Die technology. An outline of the problems and the solution developed is given below.

## 23.2. Problems and Their Constituent Sub Problems

They have been assessed as follows:

- Production rate achievement:
  - Biomass flow rate problems
  - Machine uptime problems
- Fines:
  - Escape from cyclone
  - Escape from scrapper ring
- Wear:
  - Ram, die and wear ring
  - Hammer mill blades
- Speedy moisture measurement:

## 23.3. Solution Status

**Biomass flow rate problem**

<u>Problem identification</u>

From the bunker to the taper die the biomass travels through a

- a horizontal screw
- a vertical screw working in a hopper and a chute
- a feeder box.

Observed data has indicated that each one of these stages could pose a bottleneck to the flow. Conclusive solutions have been developed and some control is needed now. A production rate of 800 kg/ hour is positively achievable against the rated 500 kg/hr. There is enough cushion power in the 40 HP motor to cater to this production rate.

Brief details of solutions

- The regulating plate over the delivery end of the horizontal feed screw needs to be cut open a little over the screw profile.
- The radial angle at which the vertical screw blade gets attached to the vertical screw stem needs to be drooping (a 15 $^0$C drooping to horizontal was tried instead of being kept horizontal).
- Ram-to-feeder box bottom gap has to be maintained at minimum levels. A replaceable feeder box bottom is under fabrication to effect speedy restoration of gap size.

**Machine uptime problems**

Problem identification

Two factors identified are i) inadequate cooling of the lube oil causing forced shutdown after 8 hours of operation. Data has been gathered and the extent of heat generated has been assessed as equivalent to 2.25 kW. The oil circulation rate and cooling area provided are not adequate to achieve a desirable 55°C lube oil temp at the bearing.

Solution

Standard design procedures can be used to design a heat exchanger which should provide for

- 10 liters of oil flow per minute
- 10 liters of water flow per minute
- A heat exchanger area of 1.4 square meters.

**Fines escaping from cyclone**

Problem identification

Pneumatic conveying system working under negative pressure requires a cyclone and an air lock feeder as part of the system. The air lock feeder is never perfect and fines are not recovered completely. They escape through the discharge of the exhaust fan.

Solution - 1

A diffuser to reduce the outlet velocity of transporting medium to less than 1 meter per second is placed downstream and the medium is then moved upward through a filter bed of sliding groundnut shell. The loaded groundnut shell is recycled. Fines collected at the bottom of the U-turn are removed through a trap and plunger arrangement intermittently. This arrangement has been proved experimentally and installed in one unit without the groundnut shell filter arrangement.

Solution - 2

A pressure cyclone is placed downstream of the exhaust fan and the collection from the bottom of the pressure cyclone is taken to the bunker.

**Fines escaping from scrapper ring**

One unit reports satisfactory outcome from using an asbestos packing ring instead of cast iron scrapper ring and another unit reports using a set of oil seals in the place of scrapper ring with very satisfactory results.

**Wear of ram, die and wear ring**

After exhaustive trials with different materials, different hard facing and surface treatments, some promises of better wear has been found in induction hardening of the ram. As for the wear ring, hardfacing suggested by diffusion engineers is being tried which is said to give maximum wear resistance to flying particles as in induced draft fans in the coal industry.

PVD is also being tried on a high carbon high chromium base. Hammer mill blade wear will be taken up for study after successfully solving the ram, die and wear ring wear.

**Speedy moisture measurement**

The capacitance variation in a standard sample with the varying moisture content has been utilized as the basis for constructing a moisture measurement device. A multimeter with capacitance measuring capability is used and calibration charts have been prepared for converting capacitance value to moisture content value for different types of biomass. The limitation in the system is that the biomass must have a consistent flow for testing in this device. It should not be sticky and hence high moisture content (above 40%) cannot be successfully tested.

# 24. Scenario of Non-IREDA Funded Briquetting Units

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## 24.1. Characteristics of Non-IREDA Funded Briquetting Plants

- High equity (70-100%).
- Small in size (10 - 30T/day).
- Labour oriented material handling.
- Large raw material stock.
- Generally single raw material.
- Low overheads.
- Niche market.
- Family run.
- Higher capacity untilisation.
- Previous experience in running industry (Khandasari units).

## 24.2. Improvement in Technology

- Old
  - Shaft with eccentric mounted crank.
  - Bigger crank shaft bearing - more problems.
  - Exposed ram - dust spoils the lube oil.
  - Availability - only 15-25%.
  - Maintenance cost Rs. 200/ton.

- New
  - Integral crank shaft.
  - Smaller crank shaft bearing
  - Covered ram - so no dust problem.
  - Availability is 45-60%.
  - Maintenance cost Rs. 100/ton.

## 24.3. Characteristics of Future Broad Based Units

- Typical size is 80 - 100 T/day.
- Mechanical material handling system.
- Multipe raw materials.
- Professionally managed.
- Low equity.
- Higher investment and lower running cost.
- Higher capacity utilisation.
- General market.
- Higher raw material cost.

## 24.4. Issues Connected With the Use of Multiple Raw Materials

- Compactness of briquettes.
- Combustion problems.
- Ash deposition.
- Clinker formation.
- Calorific value.
- Smoke/unburnt volatile matter problem.

## 24.5. R & D Requirements

- Improving the life of wear part.
- Improving the drier.
- Proportioning, Blending.
- Reducing cost of wear parts.
- R.M. Handling system.

## 24.6. Financial Analysis of Large and Small Units

| ITEMS | SMALL 1.5T/H | LARGE 3T/H | | |
|---|---|---|---|---|
| Raw materials | 550.00 | 550.00 | 593.00 | 593.00 |
| CONVERSION COST | | | | |
| Wages | 65.00 | | 75.00 | |
| Electricity | 80.00 | | 160.00 | |
| Loan repayment | 50.00 | | 150.00 | |
| Interest on term loan | 12.00 | | 83.00 | |
| Interest on working capital | 23.00 | | 20.00 | |
| Depreciation | 50.00 | | 88.00 | |
| Overheads | 30.00 | | 63.00 | |
| Incidental | 30.00 | 340.00 | 50.00 | 960.00 |
| Total expenses | 890.00 | 890.00 | 1553.00 | 1553.00 |
| Price/ton | 1200.00 | | 1626.00 | |
| Profit per ton (rs.) | 310.00 | | 73.00 | |
| Capacity utilisation | 51% | | 35% | |

## 24.7. Cost Matrix for Briquetting Different Raw Materials

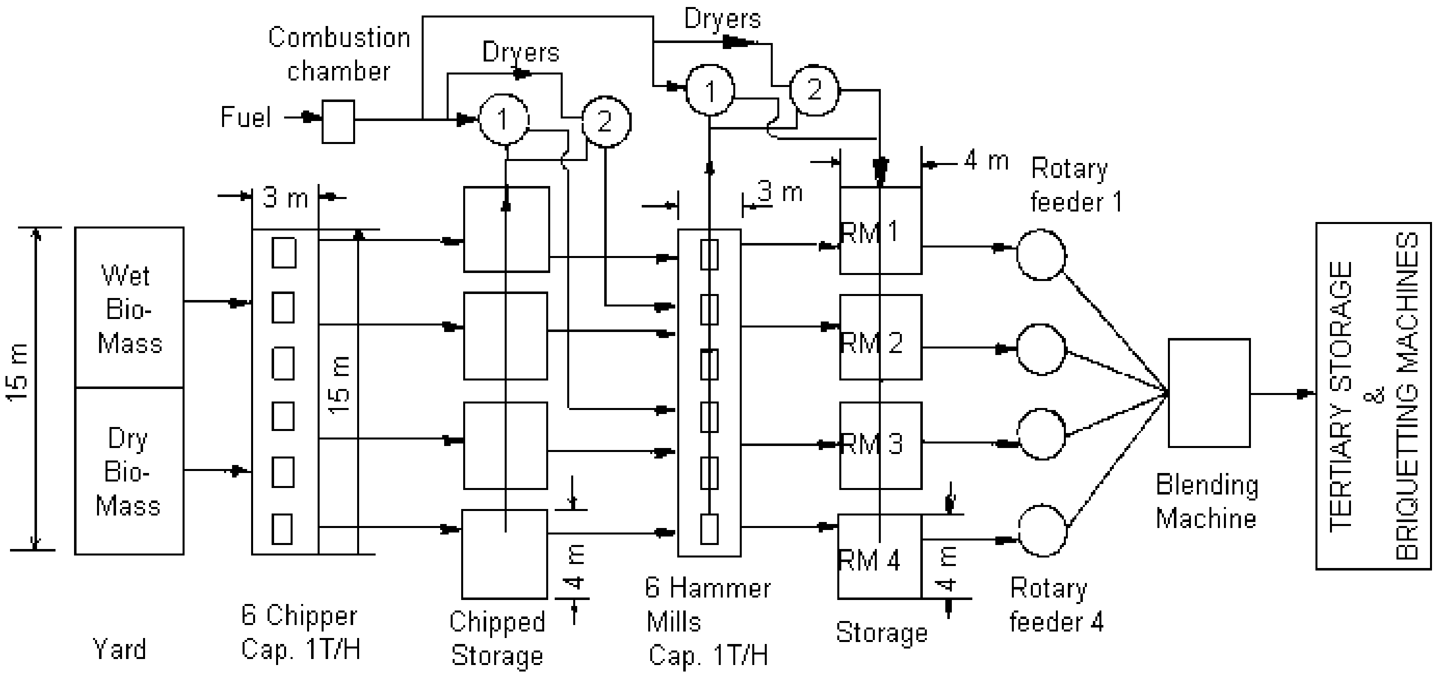
| | CHIP Rs/T | DRIER Rs/T | H.M. Rs/T | B.P. Rs/T | TOTAL Rs/T |
|---|---|---|---|---|---|
| SAW DUST* | - | 100 | - | 300 | 400 |
| G.N. SHELL | - | - | 120 | 280 | 400 |
| COTTON POCKET | - | - | 120 | 280 | 400 |
| BAGASSE | - | 90 | 90 | 270 | 450 |
| COTTON STALK | 25 | 50 | 100 | 325 | 500 |

H.M. - Hammer mill.
B.P. - Briquetting press.
* - 50 % moisture.

## 24.8. Issues Related to Material Handling System

! Silos should be provided to store raw material before and after hammer mill.
! No standard designs are available.
! Flowability, and bulk density should be taken into account.
! Segragration, blending and proportioning - to be addressed.
! Bucket conveyer should be employed to feed silos.
! Active floor - screw conveyor - to discharge from silos.
! Requires high capital investment.

# SUGGESTED LAYOUT FOR A 80 T/DAY BRIQUETTING PLANT



# 25. HARDFACING OF SCREW FOR WEAR RESISTANCE

*S.K.Mishra, IIT, Delhi, India*

## 25.1. Introduction

The screw press technology which is used for briquetting of biomass has a screw to compress the material through a taper die. The only moving part of the machine which is a screw rotating at a speed of 600 rpm is prone to more damage than the stationary contact parts because of the wear caused by the abrasive behavior of biomass. This has been found to be severe for Indian biomass, even for sawdust. Extensive damage of the screw is observed for the most abrasive material, i.e. rice husk. This screw is designed to convey the material and to compress it partially before it reaches the die. The flights of the screw are more prone to damage because of their smaller surface area. The wear caused is due to mechanical friction of biomass with the screw surface.

The cost of repairing the screw has an economic impact on the feasibility of biomass briquetting. In the research described below an appropriate hardfacing alloy for the coating of wornout screw was identified through careful analysis of all service conditions. Some of the iron based and cobalt based hardfacing alloys were tried initially. But ultimately the well known wear resistant material was found to be successful for the extended run of the screw. The base material of the screw and its weldability to tungsten carbide measures the performance of hardfacing in abrasive conditions. EN19, a low alloy steel, was found to give better performance compared to other steel alloys. The characteristics of other steel alloys may be superior to EN19, but the service conditions have proved this to be more suitable and economical.

## 25.2. Hardfacing

In this case, hardfacing was carried out by the application of a hard, wear resistant material to the surface of the screw component by welding. Before the hardfacing is done, it is necessary to know the type of wear occurring on the surface of the metal. In the case of extrusion of biomass, the wear can be classified under abrasive wear. Usually, the resulting wear pattern shows scratches and cuts and gradually this removes the metal uniformly from the screw operating at high pressure which then needs hardfacing on it to be reused. To prevent the wear of the metal the screw has to be welded with a hardfacing alloy. Economics frequently play a major role in the selection of hardfacing material. In the present context, selection of proper material was made after careful consideration of part design, wear mode and material and environmental interactions.

### Hardfacing alloy selection

The important parameters in selecting the proper hardfacing alloy are: base metal, deposition process, type of wear and thermal requirements. For the most part hardfacing alloys are either iron-, nickel or cobalt based. Carbides are extremely important for severe abrasion applications.

The ability of an alloy to retain strength at elevated temperatures is important for briquetting applications. The alloy should have hot hardness which is defined as hardness at high temperatures. The important property `hot hardness' of certain weld metals refers to metals and alloys that remain relatively hard at high temperatures, compared with conventional engineering metals such as carbon steel. Usually the hardness of weld metal falls off very slowly at room temperature but the hardness falls off much faster at elevated temperatures. It can be concluded that nothing stays hard forever; some metals just stay hard longer (when they get hotter) than other materials.

In the present context, the following steps have been taken care of in selecting a hardfacing alloy.

- Analysis of the service conditions to determine the type of wear and environmental resistance required
- Selection of several hardfacing alloy candidates
- Analysis of the compatibility of the hardfacing alloys with the base metal, taking into consideration thermal stresses and possible cracking
- Field testing of hardfacing parts
- Selection of an optimum hardfacing alloy, considering cost and wear life
- Selection of the hardfacing process for production of wear components, considering deposition rates, the amount of dilution, deposition efficiency, and overall cost, including the cost of consumables and processing.

**Hardfacing process selection**

Hardfacing process selection is as important as hardfacing alloy selection. The technical factors and the cost dictate the selection criteria. The technical factors involved in hardfacing process selection for quality requirements include:

- Physical characteristics of the workpiece
- Metallurgical properties of the base metal
- Form and composition of the hardfacing alloy and
- Welder skill.

Cost and general availability of the welding equipment and the welder skill are the determining factors in the final process selection for welding the screw with a hardfacing deposit in its application for commercial briquetting.

## 25.3. Screw Wear and Its Hardfacing

`SHIMADA' extruder uses a tapered screw for the briquetting of biomass. It is called the negative screw which rotates at a speed of 600 rpm. Fig. 1 shows the configuration of a screw used in screw press briquetting. The first section of the screw is used to convey the material which is then partially compressed at the tapering section. Finally the briquette is obtained after the biomass passes through the die and the pointed portion of the screw called the 'guide rod' helps in forming a hole at the center of the briquette.

During briquetting the sliding action of biomass combined with the high speed of the screw causes wear because the biomass gets rubbed against the surface of the screw continuously. As a result of which the screw surface i.e. the root portion of the screw and also the flights suffer damage. The wear is greater with more abrasive material because the coefficient of friction between the material and the screw surface increases. The aim of the research carried out here was to protect this surface from severe wear so that it could be used for a longer time.

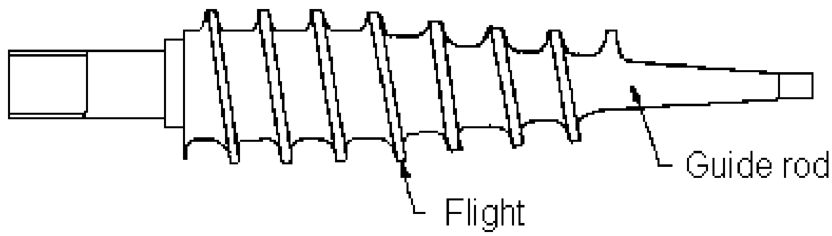



*Fig.1 Configuration of the screw.*

The steps followed to make a screw ready for the run were:

- Selection of base metal
- Making of the screw
- Hardening of the screw
- Hardfacing of screw portion exposed to wear.

For the selection of base metal a less expensive low-carbon steel, EN19, was preferred. Another low-carbon steel, EN24, is also a suitable base metal for taking up welding of hardfacing alloys, but the hardened flights of the screw show a tendency to crack under fluctuating conditions of temperature and pressure. When frequently used, the front flight taking maximum pressure was found to be broken. This material is more brittle compared to EN19 when hardened. The screw was made by a local manufacturer keeping a close watch on design considerations. The hardening procedure of the screw plays a significant role in getting the desired hardness. As half of the screw is exposed to high pressure and shearing action; the front portion being the most affected, the whole screw was hardened and then hardfacing was applied only on the front portion of the screw. For hardening (45 to 50 RC), the screw was heated to a temperature of 840 $^0$C and then oil quenched. This was then tempered to get an uniform structure throughout so that it would not break under high pressure conditions.

Several hardfacing L&T (Eutectic) alloys like Chromcarb N 6006, XHD Abratech N 6715, Eutec Dur N 9120 (stellite), Eutec Dur N 9080 (stellite) and Ultimium N 112 (tungsten carbide) were arc welded on the screw with tungsten carbide giving the best results for preventing wear. But the performance of the hardfaced screw depended on welding expertise and the pre- and post conditioning of the screw. In some of the cases a buffer materials like L&T made 680 and 2222 were deposited before finally welding the hardfacing material. Table 1 shows some of the characteristics of welding materials and their price in India.

## 25.4. Results and Discussions

### Screw performance

During the course of development, trials were taken with and without preheating the biomass. Initially sawdust was used for the purpose. The effect of preheating of biomass is pronounced in reducing the wear of the screw and thus providing a better life for the hardfacing material; consequently giving the screw a long life.

*Table 1: Information on different alloys.*

| **L&T Alloys** | | **Price per kg** |
|---|---|---|
| Name:<br>Description:<br>Claimed hardness: | Chromcarb 6006<br>Chromium Carbides in iron matrix.<br>57-60 RC | Rs. 1400/- |
| Name:<br>Description:<br>Claimed hardness: | XHD Abra Tec N 6715<br>complex carbides in iron matrix<br>63-68 RC | Rs. 2000/- |
| Name:<br>Description:<br>Claimed hardness: | Eutec Dur N 9120 (Stellite)<br>Cobalt alloy electrodes<br>45-50 RC | Rs. 6000/- |
| Name:<br>Description:<br>Claimed hardness: | Eutec Dur N 9080 (stellite)<br>Cobalt alloy electrodes<br>As deposited 30 RC, work hardened 45-50 RC | Rs. 6300/- |
| Name:<br>Claimed hardness: | Ultimium N 112 (tungsten carbide)<br>68-72 RC | Rs. 6000/- |
| **Advani Orlicon Alloys** | | |
| Name:<br>Claimed hardness: | Tungsten carbide welding rods<br>72 RC | Rs. 5800/- |
| Name:<br>Specifics: | Tungsten carbide powder spray<br>Optimal deposits 0.5 mm and maximum 1 mm deposits. Spray works with oxy-acetylene flame. Cost of equipment Rs. 14000/- | Rs. 5200/- |
| Name:<br>Hardness: | E 743 N<br>Looses hardness above 650°C | Rs. 1800/- |
| Name:<br>Claimed hardness: | Union carbides has stellite rods on oxy-acetylene gas welding<br>55-58 RC | Rs. 4000/- |

**Initial trials with sawdust and various hardfacings**

In the beginning, tests were conducted without preheating the biomass. Initially the original screws supplied with the machine were tested for briquetting but they could give a screw life of only 4 hours. The screws were hardfaced on the surface of the first flight. The wear was intensive in nature and uniform. The most affected parts were the first two flights from the side of the guide rod. Fig.2 shows the wear pattern of a screw. No conclusion could be made because the base metal and the hardfacing deposits were not known.

Results with N 6006

The screw was then welded with iron based N 6006 and trials gave only a life of 4 hours. After this it needed resurfacing. Repeated runs with hardfacing did not show any improvement on the life of the screw. In the case of severe wear the wornout portion was first welded with a buffer material 680 and then welded with 6006. The purpose of using buffer material is to make up for the high consumption of welding material and also the buffer layer deposited between the base metal and hardfacing alloy counteracts large differences in thermal expansion and contraction characteristics. Later another buffer material 2222 was used and the screw life increased to a maximum of 5 hours.

The lack of resistance of N 6006 to severe abrasive wear may be due to high temperature and pressure conditions inside the press. This material is not known for hot hardness for a prolonged time.

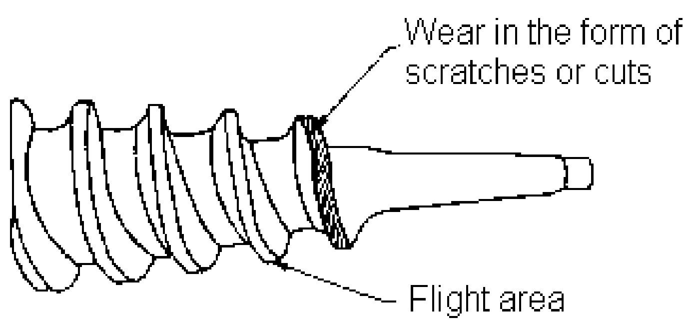



*Fig.2 Screw wear pattern.*

Results with N 6715

Another complex carbide XHD Abra Tec N 6715 in iron matrix also gave a screw life of 4-5 hours. This hardfacing material has properties almost similar to 6006 except that it can sustain at high temperature for a comparatively longer time than 6006. Accordingly a slight improvement in screw life by 1 hour was obtained.

Results with Stellites

Stellites (9120 and 9080) with the buffer material 2222 still gave inferior results of only one and half to two and half hours. Under normal conditions, these cobalt based hardfacing alloys are better than iron based chrom-carbides but are susceptible to high temperature. The hardness achieved by this deposit is only in the range 45-50 RC which is considerably less compared to the abrasive wear of the currently used biomass with associated contaminants.

Results with tungsten carbide

Then the material Ultimium N 112 (tungsten carbide) with hardness 68-72 RC and having capability to sustain strength at high temperature was tested. On its first run the screw life increased to 15 hours. Then a screw was made with EN19 and hardened and then deposited with tungsten carbide, sometimes using the buffer material 2222. This screw using sawdust without preheating gave a screw life of 17 hours. The maximum life obtained was 17 hrs and 40 minutes. Some of the poor screw life in between two successful runs may be due to uneven welding on the screw surface. The area of the flight is only 6 mm width, and an experienced welder is required to accomplish this.

In the next phase of trials, preheating of biomass was carried out and this had the effect of increasing the life of the screw. Heating changes the structure of the biomass and makes it softer compared to its raw form. This reduces the abrasion characteristics of the biomass causing less wear to the screw. In this case a hardened screw of base metal EN19 and deposited with tungsten carbide was tried which performed for a maximum of 44 hours (15.84 tonnage produced). The initial testing did not give satisfactory results for which the screw life varied from 6 to 19 hours. This may be again due to the lack of consistency in welding. Another screw under conditions also gave a screw life of 40 hours. This definitely indicates that tungsten carbide is a suitable hardfacing material for preventing wear. Other hardfacing materials tried without success were: Ni-Cr powder and Electrode 700 of L&T.

The success of this process was repeated with other biomass materials. The more abrasive material like rice husk recorded a maximum of 31 hours (15.5 tonnage produced) under the same screw conditions. Other materials like groundnut shell, coffee husk and mustard stalk also gave encouraging results using tungsten carbide on the screw. It was also found that the application of buffer material was not essential to improve the performance of the screw.

**Techniques of hardfacing**

The surface hardness and abrasive resistance of the welded deposit depends upon how much of the tungsten carbide has dissolved in the matrix and how much is left as cemented particles. The hardness of a good quality cast tungsten carbide is extremely high. The tungsten gives the weld deposit hot hardness upto 538 $^0$C. This is better than any hardened steel or other hardfacing deposit. The higher temperatures of the welding arc will let more tungsten carbide go into solution in the matrix metal than an oxyfuel welding process. So arc-welded deposits will be harder than weld metal layed down with an oxyfuel process. Tungsten carbide arc-welding electrodes are usually of 5 mm diameter which are marketed by L&T. The following conditions should be observed when welding tungsten carbide on the surface of the screw.

- The welding part should be preheated
- The arc should be of medium length with the electrode inclined at an angle of 45 in direction of travel
- An amperage of 190-240 should be maintained
- Downhill direction should be followed for less dilution.

It is well known that the smaller the dilution the greater the hardness. In this regard the following should be attended to:

- The amperage should be in the range of 190-240. Increasing the amperage (current density) increases dilution. The arc becomes stiffer and hotter, penetrating more deeply and melting more base metal
- The greater the oscillation of the electrode , the smaller the dilution
- A slow travel speed decreases the dilution

In addition, high welder skill and close control of the welding operation are necessary. With tungsten carbide a maximum of two layers can be deposited on the base metal for effective results, otherwise cracks on the surface may develop giving poor results. The weld deposit should have an even surface because tungsten carbide after welding cannot be grinded to smoothen it.

# 26. PRODUCTION OF BIOMASS BRIQUETTORS BY SMALL SCALE INDUSTRIES IN MYANMAR

*U.Tin Win, Yangon, Myanmar*

## 26.1. Introduction

Myanmar is an agricultural country with 65% of its export earnings derived from agriculture. As sufficient supply of water is the main condition for success in agriculture, construction of dams and irrigation systems have been given top priority. At the same time production of agriculture machineries within the country by small scale industries has also been encouraged to support agriculture.

Myanmar has an area of 261, 288 sq miles (676.577 sq km) of which 149,889 sq miles (388,210 sq km) or 57% is covered by forests. Environmental control and forest conservation plays an important role in conservation of the water supply. In Myanmar 95% of fuel energy is supplied by fuelwood. Per capita consumption of 0.5 ton per year amounts to over 20 million tons for the entire population. Small cottage industrial consumption amounts to nearly 10 million tons per year, giving a grand total of approximately 30 million tons of fuel wood consumption from forests.

With the growth of population, replanting of fuel wood trees alone cannot cope with the demand for fuel energy. Forest depletion could increase with vast areas turning to dry zones in the near future. Conservation of water could become a serious problem if this process is not checked in time. Substitution of fuel wood by other possible means have emerged as a necessity, especially in the rural areas of Myanmar.

As mentioned above, since Myanmar is an agriculture country, huge agriculture wastes are available in abundance throughout the country. Presently, these are either disposed of or used in their original forms uneconomically as fuelwood. Turning these wastes by briquettors into efficient energy producing fuel briquettes could save approximately 30 million tons of wood per year. On the other hand, conservation of forests, environment control and conservation of water could greatly help the governments' drive to boost agriculture production in the long run. Substituting wood by biomass briquettes in rural areas could be accomplished by the widespread introduction of briquettors. The local people could be taught to produce biomass briquettes for their own with the use possibility of generating extra income and jobs from the sale of excess to others. At a later stage, maintenance and even production of briquettors at village level by small scale industries could generate further income and jobs.

The encouragement of the Myanmar government can be assessed by their designation of 1995 as the 'Year of Fuelwood Substitution'. Educational seminars, workshops, practical demonstrations and training programmes have been conducted throughout the country to encourage the substitution of fuelwood. Committees have been formed by the government for research and development purposes and to distribute the required technology.

## 26.2. Screw Press Briquetting

My briquettor design (Fig.1) is a combination of Japanese and Chinese origin, but many modifications and innovations have to be embodied to suit the available raw material. A single machine can be used with quite a variety of raw materials to produce binderless briquettes. Installation of a preheating system has greatly improved the production rate and reduced the wear of the press screw.

Although the physical and chemical properties of briquettes have not been analyzed as yet, the performance is on the same level as fuel wood. Power requirement of the briquettor is designed so that if electrical energy is used, a motor needs 10 H.P. and a diesel engine 13 H.P. Production rate is 30-40 viss/hr (49-65 kg/hr). I have managed to sell 10 briquettors throughout the country to date. Follow up services and spares back up have been arranged for trouble free use. In Myanmar, small scale industries are quite capable of producing ferrous and non ferrous castings and shapers, lathes, drilling machine and welding shops are spread out over the entire country, creating an atmosphere where briquettors can be quite easily manufactured with locally available raw materials.

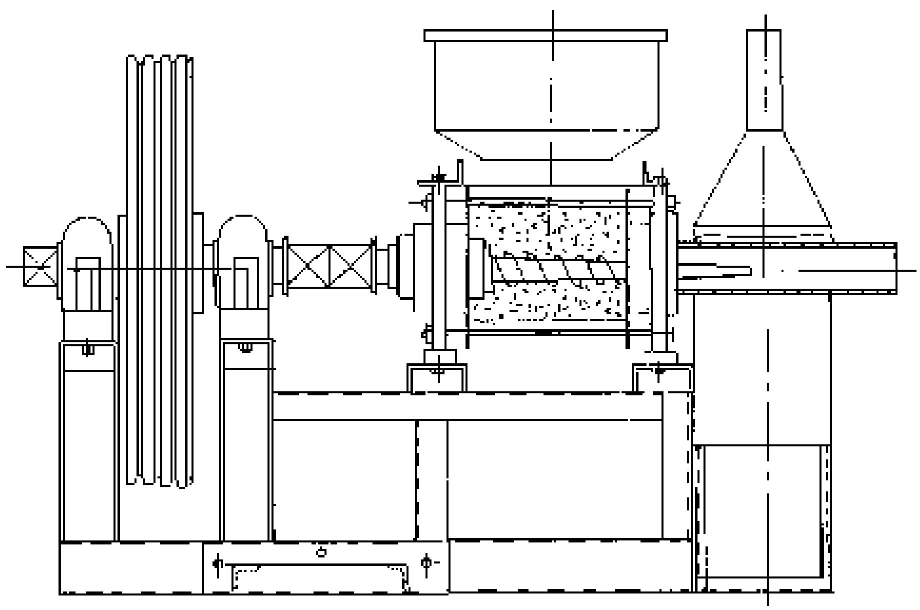


*Fig.1 Screw press machine.*

**Design features**

The design was accomplished in three stages as follows:

- Initial design, January 1995.
- Improved design after incorporation of preheating system, February 1995.
- Further improvements made after receipt of technical data and invitation from Prof. P.D. Grover, March 1995.

# 27. PROSPECTS FOR LARGE SCALE BRIQUETTING UNITS IN INDIA: A CASE STUDY

*Dr.(Mrs.) Ashalata Kulshrestha, Ahmedabad, India*

## 27.1. Project Highlights

The briquetting technology is still limited to the small scale sector in India. On account of inherent constraints faced by the small scale entrepreneurs, indigenous briquetting plants and machineries are still inefficient. If we compare the indigenous technology with state-of-the-art- technology available in other leading countries, a wide gap is clearly noticeable. Thus, technology transfer from the world leaders in the field of briquetting technology is the rule. M/s Amy Urja Vikalp Limited has entered into a "Technical Collaboration" with M/s Densi Tech BV and this has been carefully appraised by Prof. P.D.Grover, IIT, Delhi. With this Indo-Dutch collaborative effort as a basis, a proposed project is conceived to achieve the ultimate goal of efficient and environmentally compatible utilisation of 240 million tonnes of agro residues available in India. The total project outlay is estimated to be Rs. 500.00 lacs inclusive of a working capital margin of Rs. 25.72 lacs. The proposed project will be set-up in Changodar village, a backward area enjoying a state subsidy of Rs. 15 lacs. The site is 15 kms from Ahmedabad and is surrounded by an industrial belt. The project will have a term loan component of Rs. 50.00 lacs. The equity capital of Rs. 435.00 will be raised through promoters' contribution of Rs. 125.00 lacs and public issue of Rs. 310.00 lacs. The major indicators highlighting the financial viability of the proposed project are described below :

| | | |
|---|---|---|
| Installed capacity | : | 53,640 tonnes/annum |
| Anticipated capacity utilisation | : | 1st year - 60%<br>2nd year - 70%<br>3rd year - 80%<br>4th year - 90% |

**Means of finance**

| | | |
|---|---|---|
| Promoters contribution | : | Rs. 125.00 lacs |
| Public issue of equity share | : | Rs. 310.00 lacs |
| State subsidy | : | Rs. 15.00 lacs |
| Term loan | : | Rs. 50.00 lacs |
| Debt equity ratio | : | 1:9 |
| Share capital/Project cost | : | 87% |
| Share capital/Subsidy | : | 2900% |
| Share capital/Term loan | : | 870% |

**Profitability estimates**

(Rs. in lacs)

| Year | Sales | Gross Profit | Net Profit | Net cash Accruals |
|---|---|---|---|---|
| I | 448.62 | 270.38 | 147.43 | 181.67 |
| II | 543.71 | 330.47 | 168.32 | 202.57 |
| III | 621.86 | 386.59 | 190.15 | 224.39 |
| IV | 700.02 | 443.28 | 214.23 | 248.47 |

**Debt service coverage ratio**

The average DSCR for the first 8 years comes to 21.93 indicating an excellent repayment capacity. The year wise DSCR is also higher due to lower amount of loan of Rs. 50.00 Lacs compared to the project cost of Rs. 500.00 Lacs.

**Break-even analysis**

The break-even calculations for the first three years are as follows:

First year : Rs. 75.84 Lacs or 16.91%
Second year : Rs. 90.81 Lacs or 16.70%
Third year : Rs. 107.40 Lacs or 17.27%

# 28. BARRIERS TO USING AGRICULTURAL RESIDUES AS A BRIQUETTING FEEDSTOCK

*Joy Clancy, University of Twente, The Netherlands*

## 28.1. Introduction

Agricultural residues are defined as a biomass by-product from the agricultural system, and include straws, husks, shells, and stalks. These residues can be divided into two groups: crop residues, which remain in the field after harvest, for example, cotton stalk, and agricultural residues which are the by-products of the industrial processing of crops, for example, rice husk.

Agricultural residues appear an attractive feedstock since they are considered a waste material and therefore can have no intrinsic value. When they are dry the heat of combustion is similar to wood. Table 1 shows the energy potential from the major crops. Rice and wheat straws are the most important, contributing 43% of all agricultural residues. Asia has a very high potential, 45% of the total. Although the global potential is very high, the part that is recoverable is much lower, varying between 5 and 20% of the total, about 4.4 x $1010^{18}$J, which is = 1.5% of world energy demand.

*Table 1. Energy potential in $10^{15}$J of residues (straw, stalk, shells) of the main agricultural crops for 1983 in 1000 t*

| Product | Africa | Asia | Latin America | North America | Europe | USSR | Oceania | World |
|---|---|---|---|---|---|---|---|---|
| Straw | 913 | 12205 | 1543 | 5263 | 4464 | 1649 | 457 | 26882 |
| Legumes | 50 | 304 | 223 | 468 | 42 | 64 | 6 | 1157 |
| Root & tube crops | 353 | 960 | 160 | 97 | 386 | 307 | 10 | 2259 |
| Oil seed | 106 | 962 | 192 | 368 | 265 | 322 | 14 | 2180 |
| Total | 1422 | 14431 | 2118 | 6193 | 5157 | 2342 | 487 | 32478 |

LHV's in MJ/kg given as: straw 12, legumes 6; roots and tubers 6, oil seed 12.
Source: Strehler and Stutzle (1987) in Biomass (D.O. Hall and P. Overend eds), Wiley & Sons.

This paper examines some of the barriers to operating a sustainable business an entrepreneur is likely to encounter when selecting a suitable agricultural residue to act as a feedstock for a briquetting plant. Correct residue selection is a key factor in ensuring profitability since not only does the type of residue influence the wear and tear on the press but residue costs can account for at least half of all inputs.

## 28.2. Availability of Agricultural Residues

Continuous supply of feedstock is important to ensure that availability does not create a bottleneck and lead to a poor capacity utilisation factor. Credit agencies may require statistical data on the feedstock. However, it is difficult to give a precise figure for the quantity of residues available. There is little incentive for government officials to monitor the production since residues are not subjected to tax and many are not usually traded as part of the monetarised economy. Estimating the physical amounts generated is not easy. Measurements are not usually made at the point of production but rely on the use of ratios of residue produced to crop yield. Individual crop ratios are highly variable and depend upon a number of factors, including crop variety, agricultural practices (which includes variations in harvesting techniques, for example, in how much straw is removed with the grain) and site conditions, so they need to be used with caution and should be determined on a country by country basis. For example, Bhattacharya and Shrestha (1990) report in a survey of crop residues in Thailand, finding 200 different types of rice being grown and the varieties vary with the season. The range in paddy straw ratio was 1:1.388 to 1:2.131 which could lead to significantly different results if only one value was used to estimate the potential. For the entrepreneur this could lead to equipment standing idle or having to pay a higher price for residues due to shortfalls in supply.

The calculated figure for residues produced represents a maximum and the amounts actually available are in reality lower since not all residues are technically recoverable or economic to collect, there are a number of competing uses and there are losses for example, due to pests and in handling during collection, storage and transport. There is also a fraction which, for environmental reasons, such as protection against erosion and maintaining soil fertility, it is not advisable to remove. These additional constraints are now considered in detail.

## 28.3. Socio-Economic Constraints

Residues have many uses in the villages of developing countries, both agricultural and non-agricultural, which would be potentially threatened if residues were diverted to use as a briquetting feedstock. The uses are as fertilizer, fodder, fuel, fibre and feedstock for chemicals (sometimes known as the "5Fs - see Fig.1). Many of the uses are site specific and are difficult to identify from aggregated statistics. Residues are used in rural industries as well as for domestic and farm uses. Table 2 shows some examples from Nepal.

Competing uses do not exclude these residues from use as a briquetting feedstock and an entrepreneur may feel that market forces should be allowed to operate. However, government policy may influence credit agencies on what feedstock they are prepared to release funds for. On the other hand replacement of residues as a household fuel by a higher quality fuel (for example, kerosene) could have significant impact on indoor air quality by reducing the level of particulars emissions which would reduce the incidence of lung and eye diseases in women and children. Fuel switching may be a policy governments are keen to promote, thereby releasing potential briquetting feedstock material.

Crop residues are generally scattered and would require considerable effort to collect. Unless farmers are all compensated for their efforts they will place a low priority on collection especially since this activity would compete with other post-harvest activities. Mechanisation would improve the efficiency of collection but, in addition to the technical constraints discussed below, mechanisation, if available, would add to the farmer's costs. Agro-processing residues do not suffer from this collection problem since they are generated at a central location. Annexation of a briquetting plant to an agro-processing industry with a residue disposal problem, for example rice mills, has a significant advantage for cost
savings.

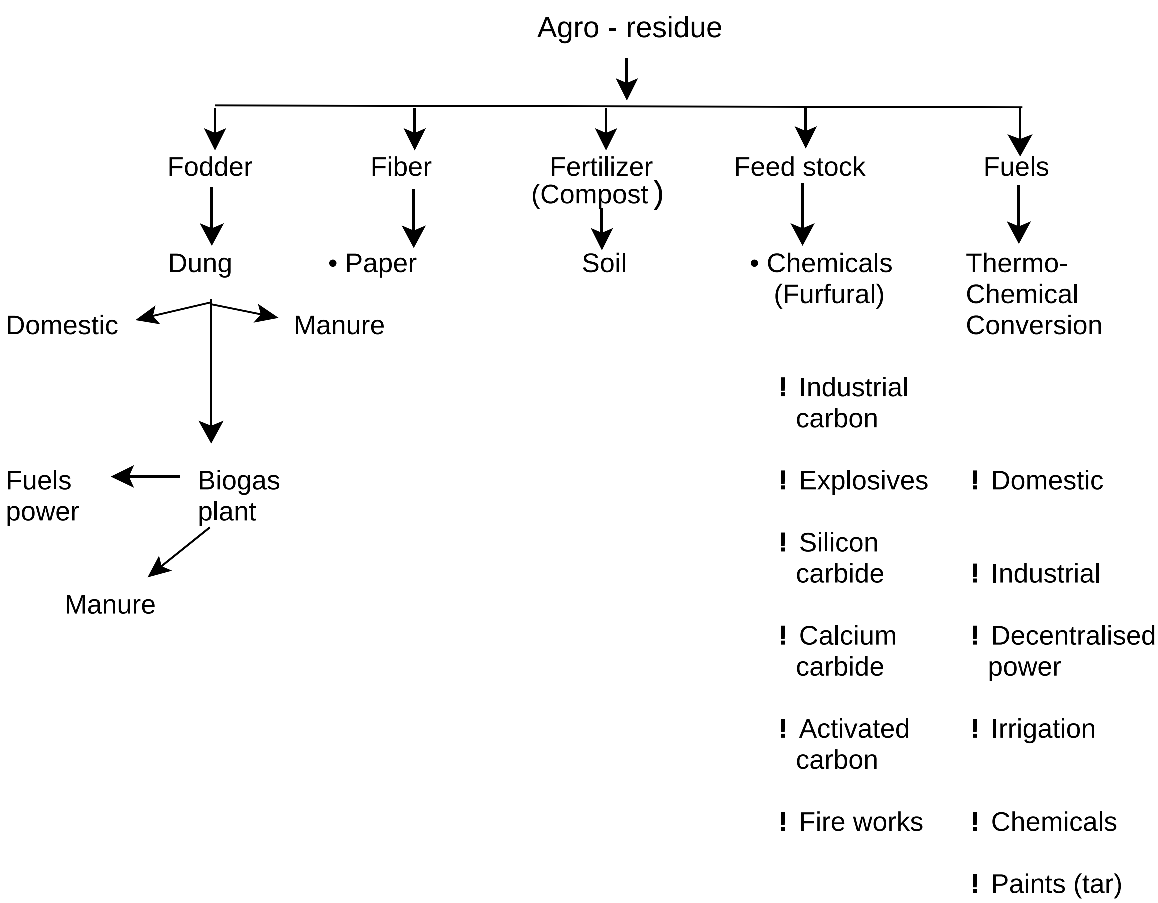



*Fig.1 The "5 F's" of agricultural residue utilization.*

The entrepreneur's investment and operating costs will need to be recouped. This means that briquettes will have to be traded within the monetarised fuel economy. Many entrepreneurs have been attracted to briquetting because the size of the household fuel market is potentially enormous. Every household needs a daily supply of energy to meet its cooking requirements. In developing countries most people still use fuelwood or charcoal. The gap between supply and demand is well publicized and entrepreneurs have hoped to bridge that gap with briquettes. However, rural people, who make up the majority of the population, do not consider they have a problem and still obtain what they perceive to be sufficient fuel for free. Rural people are therefore unlikely to buy a low grade fuel such as briquettes. Working on an incorrect assessment of the market has led many entrepreneurs to overestimate the size of their potential market and mis-calculate the likely return on their investments. Entrepreneurs are also not competing on a level playing field since many governments continue to distort fuel prices and briquettes still have to compete against subsidised fuels.

*Table 2. Use of agricultural and forestry residues in Nepal.*

| Crop residue | Use |
|---|---|
| Rice husk | Briquetting industry; boiler and furnace fuel; rice husk cement industry |
| Sawdust | As a fuel in cooking stoves; briquetting industry |
| Wood | Cooking purposes; construction materials |
| Rice straw | Cattle feed; fuel; compost; paper industry |
| Wheat straw | Cattle feed; fuel; compost; paper industry |
| Maize straw | Cattle feed; fuel; compost; briquetting |
| Pigeon peastalks | Cooking purposes; construction materials |
| Dung (cow & buffalo) | As fuel for cooking; compost; biogas production |

Source: Shree Krishna Adhikary (1990) "Current status and future prospects of rice husk and other biomass gasification technologies in Nepal" in Agricultural Residues as an Energy Source, ESCAP Seminar.

## 28.4. Technical Constraints

There are two specific areas where technical constraints hinder the exploitation of agricultural residues as a briquetting feedstock. The first is for those field residues which have no competing uses, collection would at present rely on hand gathering since mechanised methods ether do not exist or are not available at a size appropriate to fields in developing countries.

## 28.5. Financial Constraints

It is difficult to give general advise on the financial performance of briquetting plants since the data is highly site specific. The handling, transport and storage costs are high and can form a significant part of the fuel production costs. In India, a recent study by TERI (1995) shows that transport and residue costs can make up more than 50% of total costs. However, an earlier study in Malaysia identified cost of energy, availability of labour and a steady supply of raw materials as most significant influences on manufacturing cost.

Where possible a residue should be selected which requires minimal pre-treatment, for example, paddy husk requires no drying. Storage of seasonally produced residues will be required for continuous use throughout the year to maximise the capacity utilisation factor or a mixture of feedstocks can be used but it is important to check if any variations in briquette composition affects quality and match users specifications. Continuity of supply to a user is essential if briquettes are to complete with other fuels such as fuel wood or coal.

Entrepreneurs should not assume that agricultural processing residues will have no cost. Evidence from Thailand shows that in a relatively short period of time that there has been a significant alteration in the use of rice husks, from a waste with a disposal problem to a valuable raw material, for example for firing bricks. Rice husk is now becoming increasingly difficult to obtain without a long term supply contract. This has been shadowed by a price increase. In 1988, a survey showed a maximum price of 200 baht/tonne, and by 1991, the price had reached 300 baht/tonne during the milling season and 600 baht/tonne in the off-season.

Credit institutions, such as agricultural development banks, are not familiar with briquetting technology which makes them reluctant to lend money for investment in the technology, IREDA in India is an exception which has done much to promote the technology.

## 28.6. Manpower Constraints

Collection of field residues competes with post-harvest processing and farmers will be reluctant to be diverted from their traditional tasks unless well compensated which will add to an entrepreneurs' costs. This reduces the attractiveness of unutilized crop residues.

In many developing countries there is a shortage of skilled manpower trained in the operation and maintenance of briquetting. The lack of after sales service by manufacturers and supplies of imported technologies have been the reasons why a number of briquetting plants have failed.

There is also a shortage of research and development personnel who can adapt the technologies to match local resources and needs, for example, tractors and bailers appropriately sized for small fields. This hampers the exploitation of unutilized crop residues.

## 28.7. Institutional Constraints

Entrepreneurs should appreciate that there is not as yet a fully indigenous briquetting technology in many countries. This means that the technology does not as yet, except in a few isolated examples, function completely satisfactorily since it has not been optimized for local conditions of feedstock type and quantity availability. One of the objectives of the Biomass Densification Research Project (BDRP) undertaken by the University of Twente in collaboration with IIT,Delhi, has been to develop a technology which is more suitable for use in the South and South East Asian region. Reported elsewhere in  this workshop are the technical findings of the research which should help in the spread of a more appropriate technology. This workshop has been convened to communicate the research findings and to promote an exchange of information between briquetting entrepreneurs, manufacturers of equipment, research institutes, government agencies and other relevant agencies. This type of communication has in the past been weak and has hindered the development and dissemination of the technology.

A lack of an indigenous briquetting press manufacturer also means that the commissioning, maintenance, spare parts and back-up facilities, infrastructure is weak and has been heavily reliant on imported technology and expertise. This can lead to significant costs incurred by the entrepreneur and has been a major cause of failure of projects in the past.

Entrepreneurs have not always adopted modern business approaches to establish and manage a briquetting plant. Briquettes are a new product and the market does not perceive the advantages of briquettes over fuelwood. Marketing strategies are lacking. This was specifically identified in the Philippines as a barrier to further dissemination.

## 28.8. Environmental Constraints

These may not be as great a barrier as might at first be envisaged. Not all residues make good fertilziers and farmers already actively select those residues best suited to this purpose. The response of crops to organic manures is extremely varied, some crops show dramatic increase while others show little effect. What is apparent is that the effect on the crop depends upon the type of soil and the preparation and method of application of the compost. Probably of much greater significance is the effect of residue removal on erosion both from the wind and water. Some residues make reasonable substitutes for fuelwood and are utilized as such. Traditional farmers also remove field residues for a number of sound agricultural reasons; different composting abilities, disease prevention; ease of planting succeeding crops.

Any environmental problems should be identified by environmental impact assessments required by financing institutions. The most significant environmental problem in the briquetting plant is likely to be dust and fumes which can be overcome by suitable extraction equipment. This should be constructed in such a way so as not to cause a nuisance to people living in the vicinity of the plant. Preventative  action naturally adds to costs.

## 28.9. Conclusions

There have been some bad experiences with briquetting in the past. Many entrepreneurs envisaged a quick and large profit form turning a "free" waste into a product to meet fuel storages. Entrepreneurs have under-estimated what appears to be a simple operation. There have been problems with the technology being inappropriate for local conditions. BDRP has gone a long way to addressing these and good solutions have been identified. However, what is most important is for entrepreneurs to understand the market they are trying to serve.

## 28.10. References


- Bhattacharya, S. C. and Shrestha, R. M. (1990), Biocoal Technology and Economics, RERIC, Bangkok Thailand ISBN 974-8201-414.

- TERI (1995), Guidelines for the appraisal of investment plans for briquetting plants and study of social acceptability of briquettes as a fuel, Report prepared for BDRP II.

# 29. FINANCIAL APPRAISAL OF BRIQUETTING PLANTS

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## 29.1. Introduction

Several biomass briquetting machines have been installed in India and the Indian government is providing a number of incentives to promote the industry, such as soft loans and concessions. Even then, many briquette manufacturers are finding it difficult to repay their loans in time. This may be due to the fact that the input cost of the raw material affects the profitability of the briquetting plant. It should be noted that the input cost varies due to fluctuations in the price of raw materials transportation costs, and the distance from which it has to be procured. The present state of briquetting technology is neither well developed nor standardized. There are severe problems of material wear and tear and problem with overall maintenance of machines resulting in high down time and low profitability. Therefore it becomes necessary, both for the financial institution lending the money and for the investor who wants to install a briquetting plant, to carry out a financial appraisal of the proposed project. The purpose of this financial appraisal is to confirm first that the assumptions made in computing the future projections are realistic, and secondly to establish that the project would have sufficient surplus funds left after making all the necessary repayments to the lending institution.

## 29.2. Methodology

A number of briquetting firms operating in different parts of the country were visited for collecting factual data on different briquetting processes and their important operating factors and individual costs and revenue items. The operating conditions for different firms vary in different parts of the country. This is because they are spread over large geographical distances and consequently operate in unique business environments. The types of raw materials used and their costs, the transport costs both for inward and outward freight and other basic costs vary from one region to another. Accordingly, different models have been developed, as shown in Table 1, to represent the feasibility of typical units operating in the unique environments of the Western, Southern and Northern regions. Each of these location specific models have been developed from the point of view of a lending agency such as IREDA appraising the commercial viability of a private firm.

*Table 1. Description of cases developed.*

| Case/Region | States | Common raw material used |
|---|---|---|
| I. Western | Gujarat, Maharashtra, Madhya Pradesh | Saw dust, groundnut shell, bagasse, cotton stalk/pods, paddy husk |
| II. Northern | Uttar Pradesh, Punjab | Saw dust, cotton stalk, bagasse, mustard stalk |
| III. Southern | Tamil Nadu, Karnataka, Andhra Pradesh | Saw dust, groundnut shell, coffee husk, coir pith, rice husk |

**Assumptions**

Only a few important assumptions were made in order to simplify the analysis; these are as follows:

Raw material:

There are a number of different agro-residues used as raw material for the briquettes. No two units, even within the same region, use the same combination of material and the choice depends on a number of considerations including proximity, cost and individual preferences. Also in different seasons the same unit varies the combination used because of changes in availability.

However, there is a pattern in the consumption of raw material used within a region and for the purpose of determining the combination of raw material used for the analysis. The ratios of the different raw materials used for different cases are shown in Table 2.

*Table 2. Raw material: product mix (%), material and transportation cost.*

| Raw material | Product mix (%) | | | Raw material cost (Rs./ton) | | | Transportation cost (Rs./ton) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Case I | Case II | Case III | Case I | Case II | Case III | Case I | Case II | Case III |
| Sawdust | 35 | 40 | 35 | 450 | 425 | 400 | 175 | 100 | 175 |
| Paddy husk | 5 | --- | --- | 350 | --- | --- | 175 | --- | --- |
| Leaves | 5 | --- | --- | 150 | --- | --- | 150 | --- | --- |
| Cotton stalk | 5 | 20 | --- | 175 | 375 | --- | 150 | 75 | --- |
| Cotton pods | 5 | --- | --- | 250 | --- | --- | 150 | --- | --- |
| Groundnu t shell | 30 | --- | 25 | 550 | --- | 400 | 150 | --- | 200 |
| Bagasse | 15 | 20 | --- | 400 | 550 | --- | 200 | 100 | --- |
| Mustard stalk | --- | 20 | --- | --- | 550 | --- | --- | 75 | --- |
| Rice husk | --- | --- | 5 | --- | --- | 250 | --- | --- | 250 |
| Coir pith | --- | --- | 15 | --- | --- | 200 | --- | --- | 150 |
| Coffee husk | --- | --- | 20 | --- | --- | 450 | --- | --- | 150 |

Inward freight:

Inward freight costs vary from one unit to another within a region on account of factors such as the proximity to the source of raw materials. The closer the unit is to urban areas, the higher is the cost of inward freight due to the larger distances required to be covered in transporting the raw material. It was found that most of the operating units were in small towns in close proximity to the required raw materials. This did result in higher costs of transporting finished goods, but the costs of transporting raw material per ton-km was higher and it was more feasible to locate the units closer to the source of raw material. Therefore, for the purpose of our analysis, we have assumed that the unit would be close to the source of raw material and have determined freight rates accordingly for each of the regions. The average raw material cost and its freight charges for different cases are shown in Table 2.

Working year for unit:

A briquetting unit is able to work in the dry months only because of its very nature and remains closed during the monsoon months. As such the working year for a unit is taken to be nine months only.

Increase in cost:

The rates of increase which have been taken into account for the different cost elements are shown in Table 3.

*Table 3. The rate of increase for different cost elements.*

| Sr. No. | Item | Annual cost increase (%) |
|---|---|---|
| 1. | Sales price | 7% |
| 2. | Raw material cost | 7% |
| 3. | Power | 6% |
| 4. | Direct labour & factory supervisory staff | 6% |
| 5. | Repairs & maintenance | 8% |
| 6. | Miscellaneous factory expenses | 7% |
| 7. | Administrative expenses | 10% |
| 8. | Selling expenses (other than outward freight) | 10% |
| 9. | Outward freight | 5% |

Interest rates:

The commercial rate of interest charged normally by financial institutions amounts to around 15% per annum. However, for the purpose of setting up a briquetting plant, development finance is expected to be available from IREDA and the rate of interest for the same is 8.5%. Therefore, these interest rates have been used in the present analysis.

Output of each unit:

Each of the units is assumed to have two briquetting machines with an output of 500 kg per hour. The unit would operate for two shifts of 8 hours each in a day and as mentioned earlier, would remain functional for 9 months in the year. This corresponds to 225 working days, amounting to production of 3,600 tonnes briquettes annually.

However, a number of shut downs are expected for repairs and maintenance and on the basis of the field visit this has been taken as 30% of the total time. Therefore, for the purpose of preparing the financial feasibility, total output per unit per year is taken as 2500 tons.

Capital structure:

Financial Institutions in India provide long term funds against tangible assets only. 100% finance is not made available and the financial institutions finance 80 to 85% of the value of the tangible assets. The remaining `Security Margin' is expected to be financed, along with the intangible assets like preliminary assets, contingencies etc. by the promoter himself. Net working capital is financed upto 75% by commercial banks while the remaining has to be financed by the promoter himself. For the purpose of our analysis, we have assumed that the unit is fully levered to the extent possible and for this a security margin of 33% is taken. This would bring a debt-equity ratio (DER) of around 1.5:1 and a debt service coverage ratio of around 1.5, which are the norms required by financial institutions for untested technologies. The cost of each item is shown in Table 4.

## 29.3. Cash Flow Statement Calculations

### Sales

Net sale price is taken as Rs. 1300 per ton in the first year. The actual sale price varies from Rs. 1100 to Rs. 1500 per ton. Rs. 1300 per ton is thus the average price. This price is assumed to rise by 7% annually reflecting the average inflation rates.

*Table 4. Cost of the project.*

| Description | Amount in Rs. `000's |
|---|---|
| Land | 150.00 |
| Building | 350.00 |
| Plant & machinery | 1500.00 |
| Miscellaneous factory assets | 75.00 |
| Office furniture, fittings | 15.00 |
| Preliminary & pre-operative | 20.00 |
| Contingencies | 25.00 |
| Margin for working capital | 220.00 |
| **Source of Financing** | |
| - Share capital - equity | 718.68 |
| - Capital subsidy | 236.25 |
| - Term loan | 1400.30 |
| | **2355.23** |

**Raw material consumption**

The raw material consumed refers to total consumption in the manufacturing process for the year. This includes raw material consumed in briquettes sold and consumption in work-in-progress and finished goods stock (consumption on work-in-progress and finished goods stocks are adjusted subsequently to arrive at gross profit).

**Power**

The power costs used are Rs. 2.25 per unit for Western India (Case I), Rs. 2.50 per unit for North India (Case II) and Rs. 2.00 per unit for South India (Case II). Power costs are assumed to rise at 6% annually.

**Direct labour**

In calulating direct labour, the staff requirements for each unit are taken as follows:

Unskilled labour for loading : 15 @ Rs. 600 each per month, drying, cleaning etc.
Semi-skilled for overlooking : 3 @ Rs. 750 each per month above and routine operation
Primary operators cum mechanics : 2 @ Rs. 2000 each per month
Factory supervisor : 1 @ Rs. 3000 per month

Direct labour costs are assumed to rise at 6% per annum.

**Repairs and maintenance**

In our analysis, we have assumed that the main operators themselves repair the machinery and replace parts when required, as is the normal practce among the units visited. The main costs therefore are of the spare parts. The costs have been derived on the basis of the average life of each of the components at their replacement cost. The machineries are assumed to run for an average of 2700 hours a year. The main spare parts and the associated annual costs are shown in Table 5.

*Table 5. Cost and life of different spare parts.*

| Part | Average life (hrs) | Cost (Rs./year) | Annual repair cost (Rs./machine) |
|---|---|---|---|
| Die | 400 | 2,000 | 13,500 |
| Ram | 250 | 1,500 | 16,200 |
| Split die | 400 | 800 | 5,400 |
| Wear ring | 100 | 250 | 6,750 |
| Oil | Rs.40/ton production | | 1,00,000 |
| Miscellaneous | Rs. 1,000/month | | 12,000 |

Repair and maintenance costs are assumed to rise by 8% annually.

**Miscellaneous factory expenses**

Miscellaneous factory expenses refer to extraordinary expenses which occur and which have not been taken into account under any other head. This has been taken at Rs. 100 per month under each of the different cases.

## 29.4. Results and Discussion

The summary of the income and cash flow statement for the various cases considered for different regions are given in annexures I-III. The share of different cost elements in production cost of briquettes for different region is given in Table 6.

*Table 6. Share of different cost elements in production cost for different regions.*

| | Case I | Case II | Case III |
|---|---|---|---|
| Raw material | 48.7% | 56.6% | 43.9% |
| Power | 13.5% | 12.9% | 15.6% |
| Labour and plant overheads | 9.3% | 10% | 9.7% |
| Repair and maintenance | 7.8% | 8.3% | 8.1% |
| Inward freight cost | 19.8% | 11.6% | 22% |

The financial analysis of units representing different regions is summarized in Table 7 in the form of different financial operating parameters.

*Table 7: Comparison of financial analysis (average) for 5 years operation.*

| | Case I | Case II | Case III |
|---|---|---|---|
| Gross profit margin | 29% | 34% | 32% |
| Debt-service coverage ratio (DSCR) | 1.35 | 1.53 | 1.47 |
| Net present value (NPV) (Rs.'000) | 13.73% | 19.38% | 17.76% |
| Total | 358 | 945 | 690 |

**Case I: Western region**

The operating and cash flow statements of a typical unit operating in the Western regions are shown in Annexure I. The gross profit margin in this region is the lowest at 29% of sales value. This is primarily on account of the high transport costs at 19% of the cost of prodcution and high raw material cost which comes to 49% of the cost of production.

A unit operating under these conditions has a debt service coverge ratio (DSCR) of 1.35 which is again the lowest amongst the units in the three regions. However, the unit is able to generate adequate reserves and cosidering that the loan repayment period of six years with repayment beginning in the first year itself, the risk factor for the lending agency seems to be adequately covered.

However, one factor must be taken into account which is that no dividend payouts are made in the first two years of operation and the only returns to the owner are in the form of director's salary during these two years. The internal rate of return (IRR) for this case is 13.73% and the net present value (NPV) is Rs. 358.09 lacs.

**Case II: Northern region**

The operating and cash flow statements of a typical unit operating in the Northern region are shown in Annexure II. The gross profits for a unit operating in this region seems to be the highest amongst the three regions at 34%. This is despite the fact that raw material costs make up to 57% of the cost of prodution. The low cost of production is on account of the very low rates paid for inward freight which amounts to only 12% of cost of production.

The debt service coverage ratio (DSCR) is the highest amongst the three regions at 1.53. This is in spite of dividends paid from the first year itself and this indicates a more than satisfactory risk cover for the lending agency.  The internal rate of return (IRR) for this case of 19.38% and the net present value (NPV) is Rs. 945.07 lakh.

**Case III: Southern region**

The typical operating and cash flow statements of a typical unit operating in the Southern part of India are shown in Annexure III. The gross profit margin for this unit is 32% and this relatively high profitability results in a DSCR of 1.47 after taking into account dividend payouts from the first year itself indicating satisfactory safety for investments in this area. Raw material is the cheapest in the country at 44% of cost of prodcution but this is offset by the very high transportation costs which come to around 22% of cost of prodcution.

The internal rate of return in the third case is 17.76% while the NPV is Rs. 690.61.

**Annexure I**

Summary of Income and Cash Flow Statement (Case I)

(All Figures in Rs. '000)

| Period in years | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Sales in tons | 2500.00 | 2500.00 | 2500.00 | 25000.00 | 2500.00 |
| **I. Net Sales** | **3250.00** | **3477.50** | **3720.93** | **3981.30** | **4260.09** |
| (A) Raw material | 1140.68 | 1204.78 | 1287.74 | 1378.76 | 1475.26 |
| (B) Total utilities | 317.24 | 336.27 | 358.45 | 377.83 | 400.50 |
| (C) Labour and plant overheads | 219.00 | 232.14 | 246.07 | 260.83 | 276.48 |
| (D) Total other factory overheads | 661.58 | 681.71 | 7.30.97 | 784.77 | 841.99 |
| **II. Cost of production (A+B+C+D)** | **2338.49** | **2454.91** | **2621.22** | **2802.20** | **2994.24** |
| Less increase in WIP | 8.26 | 0.42 | 0.59 | 0.64 | 0.58 |
| Sub-total | 2330.23 | 2454.48 | 2620.63 | 2801.55 | 2993.65 |
| Less increase in finished goods | 20.79 | 1.03 | 1.46 | 1.61 | 1.71 |
| Sub-total | 2309.44 | 2453.45 | 2619.15 | 2799.94 | 2991.95 |
| **III. Cost of Sales** | **2309.44** | **2453.45** | **2619.15** | **2799.94** | **2991.95** |
| **IV. Gross Profit (I-II)** | **940.56** | **1024.05** | **1101.77** | **1181.45** | **1268.14** |
| (E) Total Administrative expenses | 90.20 | 99.43 | 109.61 | 120.85 | 133.26 |
| (F) Total selling expenses | 315.00 | 335.10 | 355.49 | 377.25 | 402.30 |
| **V. Profit before Interest and Tax (IV-E-F)** | **534.36** | **589.52** | **636.67** | **683.67** | **732.58** |
| (G) Total financial expenses | 203.27 | 191.10 | 179.29 | 167.90 | 157.05 |
| (H) Depreciation | 276.50 | 236.58 | 202.97 | 174.00 | 149.23 |
| **VI. Operating Profit (V-G-H)** | **54.58** | **161.57** | **254.97** | **341.44** | **426.30** |
| (I) Preliminary expenses written off | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| **VII. Profit/loss before Tax (VI-I)** | **54.58** | **156.57** | **249.42** | **336.44** | **421.30** |
| (J) Provision for tax | 0.00 | 0.00 | 0.00 | 0.00 | 223.29 |
| **VIII. Profit/Loss after tax (VII-J)** | **54.58** | **156.57** | **249.42** | **336.44** | **198.01** |

| Period in years | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|---|
| **Sources of Funds** | | | | | | |
| Share capital issue | 718.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Capital subsidy received | 0.00 | 236.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| Funds from operations | 0.00 | 331.08 | 398.42 | 457.39 | 515.44 | 575.53 |
| Increase in long term borrowing | 1636.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in bank borrowing for working capital | 0.00 | 521.43 | 37.13 | 39.02 | 41.82 | 44.65 |
| **Total sources** | **2355.23** | **1088.76** | **435.55** | **496.40** | **557.25** | **620.18** |
| **Application of Funds** | | | | | | |
| Capital expenditure for the project | 2135.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in working capital (other than cash) | 0.00 | 741.66 | 51.50 | 55.30 | 59.29 | 63.34 |
| Decrease in long term borrowing | 0.00 | 469.63 | 233.38 | 233.38 | 233.38 | 233.38 |
| Taxation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 223.29 |
| **Total applications** | **2135.00** | **1211.29** | **284.88** | **288.68** | **292.68** | **520.01** |
| **Net surplus/deficit (cash)** | **220.23** | **122.53** | **150.67** | **207.72** | **264.57** | **100.16** |

**Annexure II**
Summary of Income and Cash Flow Statement (Case II)
(All Figures in Rs. '000)

| **Period in years** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** |
|---|---|---|---|---|---|
| Sales in tons | 2500.00 | 2500.00 | 2500.00 | 25000.00 | 2500.00 |
| **I. Net Sales** | **3250.00** | **3477.50** | **3720.93** | **3981.30** | **4260.09** |
| (A) Raw material | 1237.12 | 1305.83 | 1397.50 | 1495.32 | 1599.99 |
| (B) Total utilities | 281.99 | 298.91 | 316.84 | 335.85 | 356.00 |
| (C) Labour and plant overheads | 219.00 | 232.14 | 246.07 | 260.83 | 276.48 |
| (D) Total other factory overheads | 450.22 | 463.76 | 498.49 | 535.53 | 575.33 |
| **II. Cost of production (A+B+C+D)** | **2188.33** | **2300.64** | **2458.90** | **2627.53** | **2807.80** |
| Less increase in WIP | 8.03 | 0.42 | 0.58 | 0.62 | 0.61 |
| Sub-total | 2180.29 | 2300.22 | 2458.32 | 2626.91 | 2807.19 |
| Less increase in finished goods | 19.45 | 1.00 | 1.41 | 1.50 | 1.60 |
| Sub-total | 2160.84 | 2299.22 | 2456.91 | 2625.41 | 2805.59 |
| **III. Cost of Sales** | **2160.84** | **2299.22** | **2456.91** | **2625.41** | **280.59** |
| **IV. Gross Profit (I-II)** | **1089.16** | **1178.28** | **1264.02** | **1355.98** | **1454.50** |
| (E) Total Administrative expenses | 90.20 | 99.43 | 109.61 | 120.85 | 133.26 |
| (F) Total selling expenses | 316.00 | 335.10 | 355.49 | 377.25 | 402.30 |
| **V. Profit before Interest and Tax (IV-E-F)** | **682.96** | **743.75** | **798.92** | **857.88** | **918.94** |
| (G) Total financial expenses | 205.81 | 193.88 | 182.24 | 171.09 | 160.47 |
| (H) Depreciation | 276.50 | 236.58 | 202.97 | 174.00 | 149.23 |
| **VI. Operating Profit (V-G-H)** | **200.65** | **313.02** | **413.71** | **512.78** | **609.24** |
| (I) Preliminary expenses written off | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| **VII. Profit/loss before Tax (VI-I)** | **200.65** | **308.02** | **408.71** | **507.78** | **604.24** |
| (J) Provision for tax | 0.00 | 0.00 | 0.00 | 266.81 | 259.78 |
| **VIII. Profit/Loss after tax (VII-J)** | **200.65** | **308.02** | **408.71** | **240.98** | **344.46** |

| **Period in years** | **Year 0** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** |
|---|---|---|---|---|---|---|
| **Sources of Funds** | | | | | | |
| Share capital issue | 718.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Capital subsidy received | 0.00 | 236.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| Funds from operations | 0.00 | 477.15 | 545.87 | 616.68 | 686.78 | 756.47 |
| Increase in long term borrowing | 1636.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in bank borrowing for working capital | 0.00 | 535.91 | 38.54 | 40.17 | 42.99 | 45.96 |
| **Total sources** | **2355.48** | **1249.31** | **588.41** | **656.84** | **729.78** | **804.43** |
| **Application of Funds** | | | | | | |
| Capital expenditure for the project | 2135.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in working capital (other than cash) | 0.00 | 756.39 | 53.04 | 56.53 | 60.49 | 64.71 |
| Decrease in long term borrowing | 0.00 | 469.63 | 233.38 | 233.38 | 233.38 | 233.38 |
| Taxation | 0.00 | 0.00 | 0.00 | 0.00 | 266.81 | 250.78 |
| **Total applications** | **2135.00** | **1226.02** | **286.42** | **289.91** | **560.68** | **557.87** |
| **Net surplus/deficit (cash)** | **220.48** | **23.29** | **301.99** | **366.93** | **169.10** | **246.56** |

**Annexure III**

Summary of Income and Cash Flow Statement (Case III)

(All Figures in Rs. '000)

| **Period in years** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** |
|---|---|---|---|---|---|
| Sales in tons | 2500.00 | 2500.00 | 2500.00 | 25000.00 | 2500.00 |
| **I. Net Sales** | **3250.00** | **3477.50** | **3720.93** | **3981.30** | **4260.09** |
| (A) Raw material | 991.03 | 1046.07 | 1119.50 | 1197.83 | 1281.71 |
| (B) Total utilities | 352.49 | 370.11 | 388.61 | 408.05 | 428.25 |
| (C) Labour and plant overheads | 219.00 | 232.14 | 246.07 | 260.83 | 276.48 |
| (D) Total other factory overheads | 691.73 | 705.80 | 757.71 | 812.88 | 872.10 |
| **II. Cost of production (A+B+C+D)** | **2254.24** | **2354.11** | **2511.89** | **2679.62** | **2858.74** |
| Less increase in WIP | 7.77 | 0.36 | 0.55 | 0.59 | 0.52 |
| Sub-total | 2248.47 | 2353.75 | 2511.34 | 2679.04 | 2858.22 |
| Less increase in finished goods | 20.04 | 0.89 | 1.40 | 1.49 | 1.59 |
| Sub-total | 2226.43 | 2352.86 | 2509.94 | 2677.55 | 2856.63 |
| **III. Cost of Sales** | **2226.43** | **2352.86** | **2509.94** | **2677.55** | **2858.63** |
| **IV. Gross Profit (I-II)** | **1023.57** | **1124.64** | **1210.99** | **1303.84** | **1403.46** |
| (E) Total Administrative expenses | 90.20 | 99.43 | 109.61 | 120.85 | 133.26 |
| (F) Total selling expenses | 316.00 | 335.10 | 342.36 | 350.35 | 360.93 |
| **V. Profit before Interest and Tax (IV-E-F)** | **617.37** | **690.11** | **759.01** | **832.64** | **909.27** |
| (G) Total financial expenses | 210.02 | 198.31 | 186.98 | 176.15 | 165.86 |
| (H) Depreciation | 276.50 | 236.58 | 202.97 | 174.00 | 149.23 |
| **VI. Operating Profit (V-G-H)** | **130.85** | **254.95** | **369.07** | **482.49** | **494.18** |
| (I) Preliminary expenses written off | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| **VII. Profit/loss before Tax (VI-I)** | **130.85** | **249.95** | **364.07** | **477.49** | **589.18** |
| (J) Provision for tax | 0.00 | 0.00 | 0.00 | 84.49 | 225.00 |
| **VIII. Profit/Loss after tax (VII-J)** | **130.85** | **249.95** | **364.07** | **393.00** | **364.18** |

| **Period in years** | **Year 0** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** |
|---|---|---|---|---|---|---|
| **Sources of Funds** | | | | | | |
| Share capital issue | 734.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Capital subsidy received | 0.00 | 236.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| Funds from operations | 0.00 | 407.35 | 491.80 | 572.04 | 656.49 | 743.41 |
| Increase in long term borrowing | 1636.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in bank borrowing for working capital | 0.00 | 529.69 | 37.66 | 39.64 | 42.42 | 45.31 |
| **Total sources** | **2371.39** | **1173.29** | **529.46** | **611.67** | **698.91** | **788.71** |
| **Application of Funds** | | | | | | |
| Capital expenditure for the project | 2135.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Increase in working capital (other than cash) | 0.00 | 766.08 | 52.46 | 56.69 | 60.64 | 84.82 |
| Decrease in long term borrowing | 0.00 | 469.63 | 233.38 | 233.38 | 233.38 | 233.38 |
| Taxation | 0.00 | 0.00 | 0.00 | 0.00 | 84.49 | 225.00 |
| **Total applications** | **2135.00** | **1235.71** | **285.84** | **290.07** | **378.51** | **523.20** |
| **Net surplus/deficit (cash)** | **236.39** | **-62.42** | **243.62** | **321.61** | **320.40** | **265.51** |

# 30. BIOMASS BRIQUETTING: FINANCIAL ANALYSIS OF BRIQUETTING UNITS UNDER BDRP (PHASE II)

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## 30.1. Introduction

An evaluation study was conducted and certain findings were arrived at with particular reference to the market for briquettes. This evaluation entailed developing a number of measures to assess the financial feasibility of investments and to rank the various alternatives. For the purpose of the evaluation, the internal rate of return (IRR), is considered the best criterion, since it could be perceived as the discount factor at which the investment project "breaks even"; accordingly the IRR also relates to the yield of the investment. Keeping the above in view, one would like to demonstrate the conclusions employing for good measure certain graphs as part of our sensitivity analysis. One would also like to add at this juncture that the conclusions would only be true if it was established beyond doubt that the lifetime of the screw's first flight could be extended to at least 24 hours of operation and if the cost or rewelding could be brought down to Rs 500.

## 30.2. Leffer's Study and a TERI Study

Leffer conducted an ex-post evaluation of the financial performance of 6 piston type machines, after which the firm's profitability was computed. He felt that "from the point of view that profit is the most important criterion, the briquetting industry does not seem to be a very interesting project". Leffer stated the following as reasons for the lack of profitability: (i) excessive downtime (ii) high moisture content of the raw material (iii) power failure and (iv) wear of the machines. He stated that an increase in the production time is imperative to increase profits. These facts were confirmed by our visits to these plants and as well as from extensive discussions with IREDA and the manufacturers of the machines. Three firms ended up having a negative IRR (internal rate of return), and the other three showed 19.4, 27.4 and 6.5%. Leffer used current prices and in constant prices, the IRR would be 10 points lower, thus leaving only 2 out or 6 with a positive IRR. The small margin between sale prices and cost of raw materials was also considered another important factor by Leffer. Furthermore, the availability of raw materials is of utmost importance and the lack of alternative fuels such as coal and lignite as well.

TERI built a financial model, using primary data on existing briquetting plants. What was discovered was that the gross profit margins are considerable, but not yet sufficient to earn back investment in 5 years in the West and the South. The investment in the North is earned back, but the IRR still does not exceed the opportunity cost of capital. The reasons for the `non-profitability' of the venture, and how to prolong the life time of the screw are factors that, if dealt with deftly would go a long way in contributing to a substantial increase in uptime and therefore in better capacity utilization and productivity.

However, it should be pointed out that, some of the assumptions made by TERI are rather optimistic, based on certain omissions like the moisture content is stated as only 5%, implying that there is no loss of mass during the densification process.The downtime is 30%, which is based on field visits, and the highest capacity utilization does not exceed 50% of all materials. Material handling losses are estimated to be zero, whereas the suppliers of the briquetting machines indicated that at least 5% of raw materials are lost during the process. One other important feature of the TERI model is that the cost of raw materials as well as the price of the briquettes are assumed to rise by 7% annually. The cost of electricity,the input second in importance, is supposed to go up by 6% annually, as per TERI.

TERI also made no allowances for marketing. A 10% margin has to be foreseen for marketing till such times as the product has gained the required market share. And, the study disregards the fact that not all states have added briquettes to the list of goods for which no sales tax has to be paid. The high consumption of electricity in the screw type of machine is an important factor too, especially if the moisture content of the raw material employed is excessive, the cost of drying with unfavourable mass balance adds considerably to it, and although not observed by the TERI study, the mass balance, is highly relevant, regardless of the type of briquetting machine.

In our analysis, 4 types of materials have been distinguished for reasons of difference in pre-treatment, drying and milling (specifications in table below).

| Type | Moisture content | Drying | Milling | Materials |
|---|---|---|---|---|
| I | 50% | yes | yes | - coarse coir pith<br>- bagasse |
| II | 10% | no | yes | - coffee husk<br>- rice husk<br>- groundnut shells |
| III | 25% | yes | no | - sawdust |
| IV | 40% | yes | no | - fine coir pith<br>- bagasse pith |

In order to examine the impact of a number of important parameters on the profitability of the screw extruder machine, a sensitivity analysis was conducted, starting from a set of more realistic assumptions, which were :

| | | |
|---|---|---|
| Number of workable days per year | | 225 |
| Number of hours per day | | 16 |
| Downtime | | 30% |
| Captive consumption of briquettes | | 0% |
| Marketing cost | | 0% |
| Stocks: | raw materials | 11 days of consumption |
| | finished product | 2 days of production |
| | work in progress | 1 day of production |
| Price of briquettes | | Rs 1,500/ton |
| Investment subsidy | | 15% of total investment |

For the base scenario, in which the above assumptions are described, the following results were obtained:

| Materials | I | II | III | IV |
|---|---|---|---|---|
| IRR | -10.2% | 14.2% | -16.4% | 9.2% |

It appears that the screw extruder machine technology is not profitable for materials I and III: there appears to be no discount rate which equalizes the cost and the benefits of the investment in the briquetting technology. This is obviously due to an unfavourable mass balance, in tandem with a high power consumption. The sensitivity of the above results are discussed below and graphically depicted as well in Figs.1-8. As can be clearly seen, the IRR cannot become positive for materials I and III by merely reducing the downtime (Fig.1).

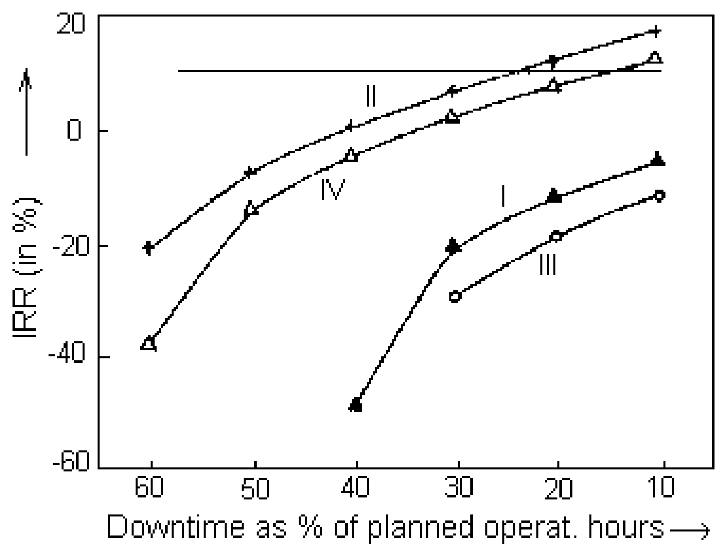


*Fig.1 Impact of downtime on IRR for materials I, II, III & IV.*

The maximum downtime for material II to retain a sufficient IRR (i.e. more than 10%) is 23% and for material IV, it is 14%. The IRR turns negative for a downtime of 40% and 33%, for materials II and IV respectively. This is an indication that the investment could only be paid back in 10 years, as long as the plant runs for more than 60% of the intended 3,600 hours per year with material II. The impact of prolonging the lifetime of the screw's first flight is much more pronounced at low values than at higher values (Fig.2). The IRR is rather insensitive to further changes if the lifetime already exceeds 24 operation hours. Besides, it also appears that for material I and III, the IRR does not become positive for any possible lifetime of the screw's first flight, under the assumptions made. At a lifetime of 40 hours, as appeared to be realistic, the IRR is 14.2-9.2%, for materials II and IV respectively.

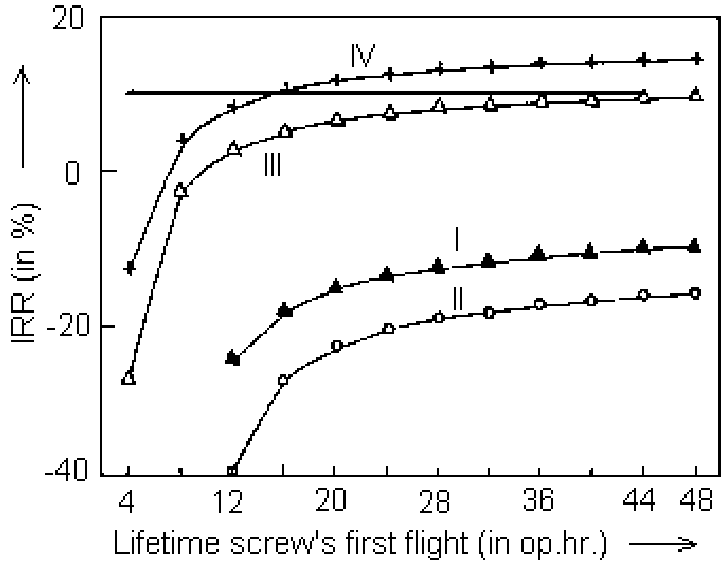


*Fig.2 Impact of lifetime of screw's first flight.*

Fig.3 depicts the changes in the IRR as a result in the planned operation hours per year, which is achievable by either changing the number of operating days per year or the number of operating hours per day. They are both, however, bound by a maximum; storage and production being limited during the rainy season, thereby limiting the working hours to 27 days per month plus maintenance and 9 months per year, or 235 days per year.

Given these limits, an investment venture can hardly be profitable, if one would like to densify materials I or III. Only a value higher than 2,200 hours per year for material II and 2,600 hours for material IV are required to render this profitable. After substraction of 16% downtime, the investment can be paid back in 10 years time, as long as the production per day is kept going at the pace of 8 to 10 hours per day on an average for materials II and IV.

This industry having a considerably high energy consumption (224-241 kWh, with preprocessing playing a key role), the price of electricity is bound to have a substantial impact on the IRR. As is seen in Fig.4, the maximum rates per kWh at which the IRR remains positive, are as follows: Rs 4.5 for type II and Rs 3.6 for type IV. As far as materials I and III are concerned, with the current electricity rates being what they are, briquetting cannot be profitable.

The price of the briquettes was Rs 1,500/ton, and it is obvious that the price of the output directly affects the IRR. The latter will remain positive for materials II and IV, for any output price higher than Rs. 1,250 and Rs 1,300 per ton (Fig.5).

It has to be noted however that if the price of briquettes is kept constant at Rs 1,700 per ton for materials I and III, the venture could be profitable, If the price becomes higher than Rs 1,900 per ton, the returns on the investment will, for all materials, even exceed the opportunity cost of the capital, assumed to be at 10%.

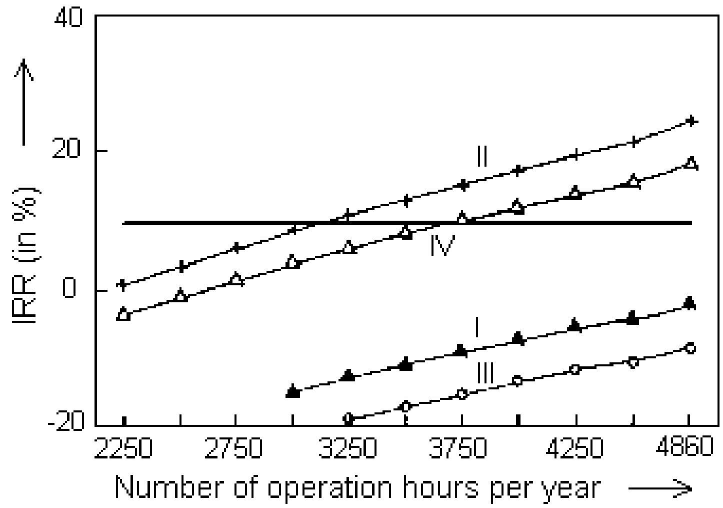


*Fig.3 Impact of planned operation hours on IRR.*

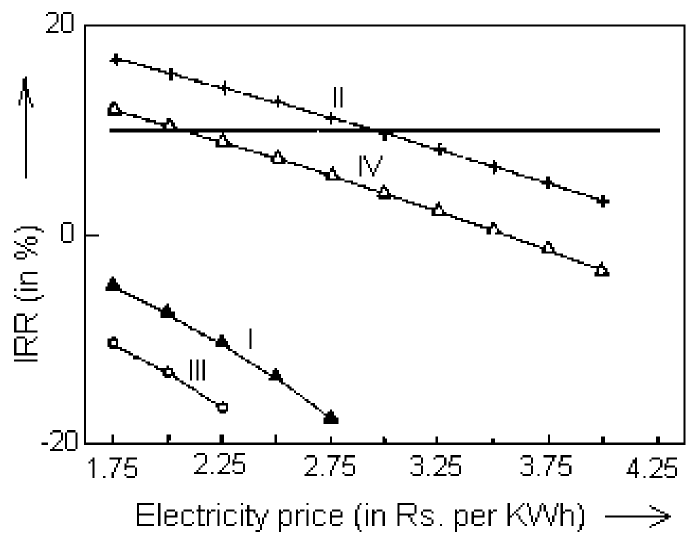


*Fig.4 Impact of electricity prices on IRR.*

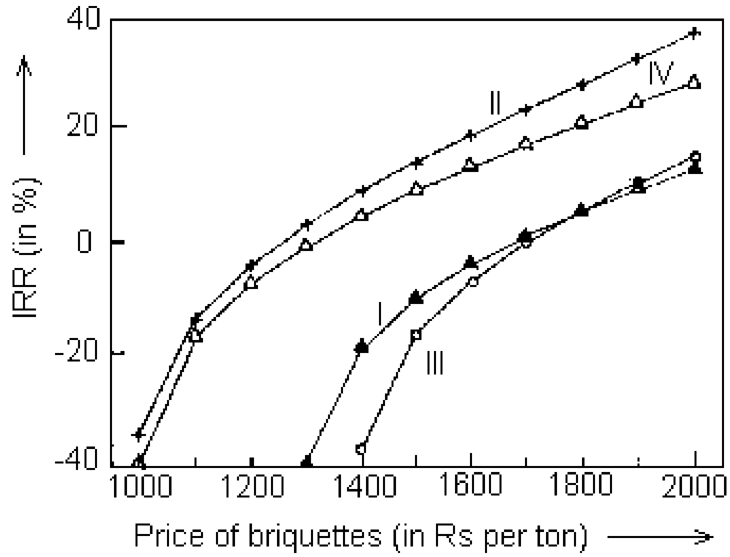


*Fig.5 Impact of price of briquettes on IRR.*

The IRR is very sensitive to changes in the price of raw materials (Fig.6). Given the large share of raw material in the total production cost, type II would more profitable than type IV, where the prices for both are the same. If the output prices do not vary, the relative profitability of course reflects the relative mass balance.

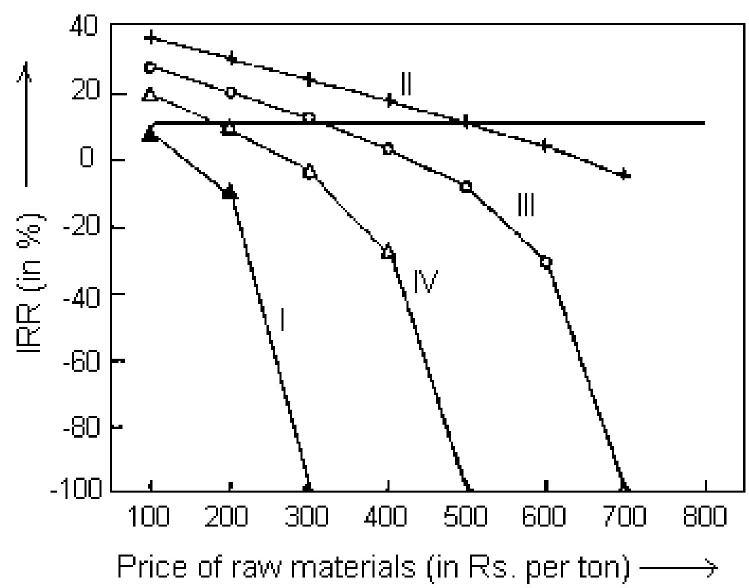


*Fig.6 Impact of price of raw materials on IRR.*

The maximum prices, with an assumed output price of Rs 1,500/ton, which would allow for a positive IRR, and an IRR higher than 10% are:

| TYPE | IRR remains positive until | IRR still higher than 10% |
|---|---|---|
| I | 150 | 75 |
| II | 280 | 190 |
| III | 425 | 320 |
| IV | 630 | 500 |

The Shimada machine, its price, including import duties, was about Rs 1.75 million or 17.5 lakh each. The manufacturer of the reciprocating piston machine said that he would be able to produce a screw extruder for Rs 3 lakhs. Presuming that this is possible, the IRR for all four types of materials would be 5% higher. Similarly, if the 25% import tax would be exempted, the IRR would rise substantially (Fig.7).

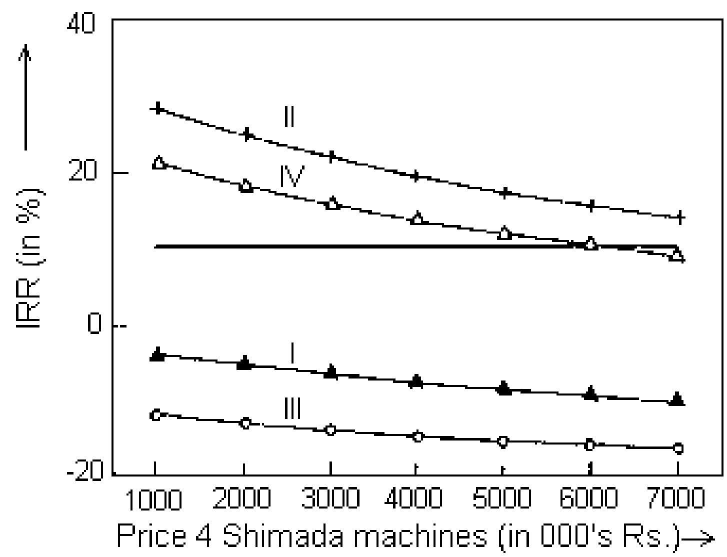


*Fig.7 Impact of price of machines on IRR.*

An investment subsidy could be instrumental in encouraging the investment in a screw press technology. The government of India does provide subsidies for industrial investment in backward areas. Each state has predefined areas entitled to such subsidies. An investor could submit an application for a subsidy. Our analysis (Fig.8) showed that such a subsidy would be far more effective that an exemption of the import tax, leading to a substantial IRR.

Without an investment subsidy, it appears that only the profitability of material II is sufficient to make screw press briquetting competitive with other investment projects. Material IV requires a subsidy of approximately 18% for its IRR to exceed 10%. An investment subsidy by itself is not sufficient to make briquetting of material type I and III profitable.

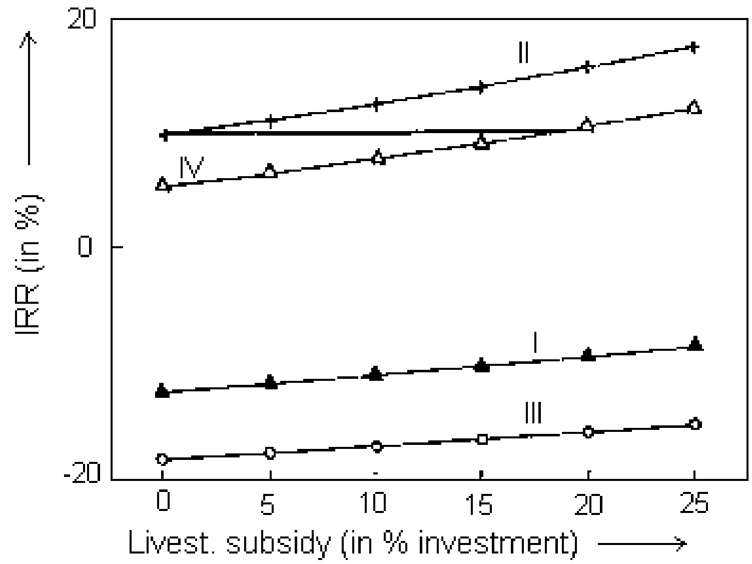


*Fig.8 Impact of investment subsidy on IRR.*

## 30.3. Conclusions

There are four measures which could promote the production of biomass briquettes.

- ! Local manufacturing of the screw extruder machine would increase the profit margin considerably by reducing the price of the machines. If the price of the machines would decrease from 17.5 lakhs to 3 lakhs, the IRR of briquetting of all types of raw materials would increase by 5 points.
- ! If the briquetting machine is to continue being imported, it would be worthwhile to add it to the list of capital items which are tax-exempted for environmental reasons.
- ! Briquetting in industrially backward areas should be supported by a subsidy of upto 25% of the value of the fixed capital investment. It would be conducive if all states in India would apply a uniform policy concerning subsidies.
- ! It would be productive to have biomass briquettes in all Indian states exempted from sales tax.

These measures would possibly help make the biomass briquetting industry a more viable industry, especially in those areas where raw materials are readily available and where there exists or could exist a scarcity of alternative fuels.