zil, India, Indonesia, and Zimbabwe, are receiving substantial support from bilateral and multilateral development sources. The success of these initiatives should further open the door to international financing for solar-based rural electrification and thus help to remove a critical barrier to the widespread use of solar electric technology in rural areas.

6. Conclusion

Solar-electric systems have proven reliable and cost-effective in the Dominican Republic, where thousands of people are now enjoying the benefits of electricity for the first time. The program's success can be largely attributed to the strength of local participation and a targeted strategy to make the technology available and affordable. ■

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Development of an appropriate biomass briquetting technology suitable for production and use in developing countries

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1. Introduction

Biomass energy currently plays a major role in meeting the present energy needs of developing countries. A number of authors (see for example, Beyea et al., 1991), have also expressed the view that biomass has the potential to meet the additional energy demands of urban and industrial sectors, thereby making a significant contribution to the economic advancement of developing countries. If this new role is to be achieved within the context of sustainable development, it is important for a developing country such as India to achieve both sustainable biomass fuel production and the more efficient utilisation of biomass. However, in order for biomass to make a significant impact as a fuel there is a need to improve and promote state-of-the-art technologies.

Of the various renewable energy sources, bio-residues, of which agricultural residues form a major component, can be most easily utilised to reduce the consumption of woodfuel (blamed partly in some areas as a factor in deforestation) (Hosier and Svenningson, 1987). Since most developing countries' economies are still primarily agriculturally based, they produce huge quantities of agricultural residues which provides an enormous untapped fuel resource. For example, in India there is a large, underutilised supply of agro-processing residues: around 49 million tonnes per annum (National Productivity Council, 1987). For a number of reasons, mainly social and environmental, it is not practical to consider using crop residues, such as rice straw, as a fuel (Clancy, 1991).

A major disadvantage of agricultural residues as a fuel is their low bulk density, which makes handling difficult, transport and storage expensive, and gives rise to poor combustion properties. However, these problems can be overcome by compacting, with a compression ratio of approximately 7:1, the loose biomass to form briquettes. The opportunity to utilise more efficiently agricultural residues, with a reduction in pollution levels, has in recent years aroused the interest of developing countries, as well as some industrialised ones, in briquetting.

Briquetting is a relatively new technology for developing countries. Although there are a number of different briquetting technologies commercially available, the challenge is to find a technology which is suited to the local market, both in terms of the briquetting press itself for local manufacture and the briquettes. In this short communication we wish to report on our initial experimental results in trying to develop an appropriate briquetting technology which meets both the technical and socio-economic criteria to be a sustainable technology, as well as bringing environmental benefits.

Although there are many briquetting plants installed by entrepreneurs in India, which have mainly used the piston extrusion presses, they have not been a complete success because of the variation in raw materials and a number of socio-economic constraints. The technologies used have also been expensive and unreliable. They generally require high maintenance and use excessive amounts of power. Sometimes the briquettes have been found difficult to ignite or burn slowly, with high levels of smoke. Also, because of irregular production patterns, arising from the intermittent breakdowns of the briquetting machines, the briquettes have not been able to penetrate the fuel market in the industrial sector. However, the potential does exist, due to the problems of intermittent solid fuel supplies in India, for a correctly designed and engineered process to allow a reasonably attractive energy recovery from bio-residues. The plant capital for the operation should be modest and the value of the fuel attractive for the industrial market. Therefore, a briquetting technology financially viable and convenient to use would ensure adoption of the technology by local entrepreneurs and the briquettes by the industrial sector.

2. Present status of briquetting technologies

In India, the briquetting industry started in 1981 with the introduction of low density and high density technologies. The former technology requires pyrolysis of the biomass followed by briquetting using a binder, to maintain the structure. On the other hand, high density briquetting technology compacts the biomass and holds the structure together without a binder. These briquettes are more acceptable to the industrial user.

There are two basic types of high compaction technology: the piston press and the screw press. Most of the units presently installed in India are of the reciprocating piston type, where the biomass is extruded through a die by a reciprocating ram at a very high pressure. In a screw extruder press, the biomass is extruded continuously by a screw through a heated taper die. In a piston press, the wear of the contact parts, for example, the ram and dies, is less compared to the wear of the screw and dies in a screw extruder press. The power consumption in the former is less than that of the latter. However, in terms of briquette quality and production procedure the screw press is superior. The central hole in the briquettes produced by a screw extruder helps in uniform and efficient combustion, with significant reductions in smoke. Also these briquettes can be carbonised which increases their energy density. The briquettes are stronger than from a piston press, making them less prone to breakage which reduces losses during handling and in the furnace. Table 1 shows a comparison between screw and piston presses.

The screw extruder press looks to be the most promising technology, with its advantages outweighing its disadvantages. Also there has been a high degree of success with machines in Europe and Japan. However, a screw extruder machine most suited to the most appropriate briquette production rate in rural India (below 1 tonne/hr), which is linked to the levels of raw material availability, is not manufactured in the country. Local manufacture of the press is an important factor in guaranteeing the sustainability of the technology, by ensuring that the skills for maintenance and after-sales service are indigenous and hence readily available. A criticism levelled at imported technology is that real technology transfer does not take place which rapidly leads to equipment being either abandoned or operated inefficiently. In an attempt to overcome these problems and provide a technology which is suited to local manufacture and adapted to local feedstocks, a collaborative project has been under way for the last year between the Indian Institute of Technology, Delhi, the Technology and Development Group, University of Twente, The Netherlands and Densitec BV (a private company also based in the Netherlands). This project is intended to overcome the technical and economic difficulties which will help in a wider dissemination of briquetting technology. The R&D strategy has been to reduce both the wear of the screw due to friction and the high power consumption. Any savings in power consumption can then be utilized to increase the throughput capacity of the machine (Bhattacharya et al., 1985).

3. The screw press technology

The press being used as part of the test work reported here is the Shimada SPMM-850 KS, which 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 to 290^{o}C to give a smooth extrusion of the briquettes. The production capacity of the machine depends on the briquette size. At present briquettes of 55 mm diameter are produced with a capacity of 400 kg/hr. If a 65 mm diameter die is used then the capacity increases to 650 kg/hr. This factor is quite important in the financial analysis of the whole plant and in the calculation of the manufacturing cost of the briquettes, and hence selling price.

Table 1: Comparison between screw extruder and piston press

	Piston press	Screw extruder
Optimum moisture content of raw material	10-15%	8-9%
Wear of contact parts	low in case of ram and die	high in case of screw
Output from the machine	in strokes	continuous
Power consumption	50 kWh/tonne	60 kWh/tonne
Density of briquette	1-1.2 gm/cm^3	1-1.4 gm/cm^3
Maintenance	high	low
Combustion performance of briquettes	inclined to crumble on grate, smoky	burns well with minimal smoke
Carbonisation to charcoal	not possible	possible
Suitability in gasifiers	not suitable	suitable
Homogeneity of briquettes	non-homogeneous	homogeneous

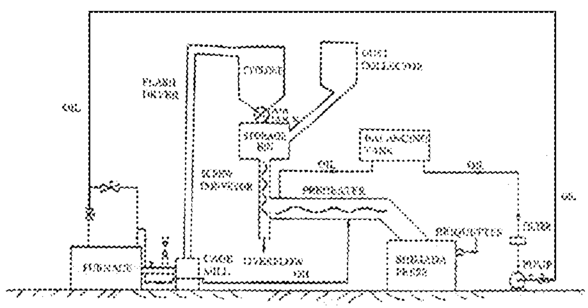


Fig. 1. Layout of a briquetting plant with preheater

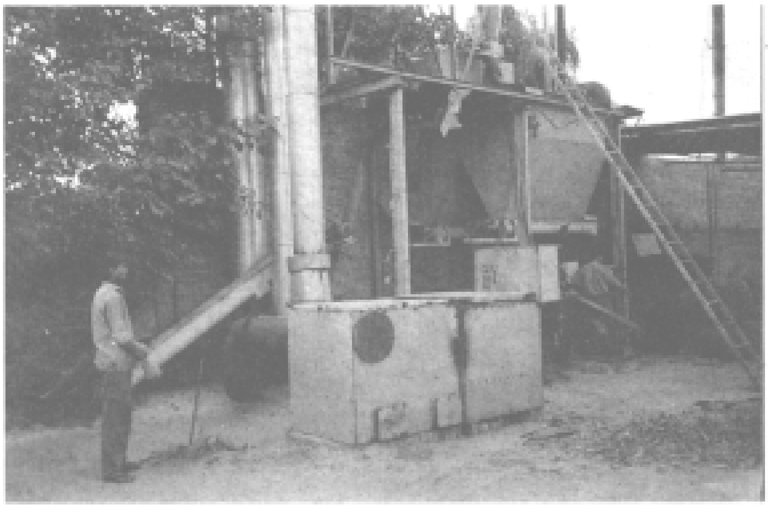
The screw press has initially been tested with sawdust. The moisture content of the sawdust available in India usually varies from 25 to 30%. Drying the material reduces the moisture content to an optimum amount of 8 to 9% and sieving allows material of suitable particle size (<6 mm) into the press.

4. Test programme and results

The whole briquette plant has been operated initially without a pre-heater to give baseline performance data.

During the briquetting process the abrasive wear on the screw is extensive. At a certain point when the surface metal loss is unacceptable the screw no longer functions and must be replaced. This time interval is known as the standing time and has a significant effect on the briquette price since changing the screw interrupts production. The more often the screw is replaced the more frequently production is disrupted.

By applying a suitable hard facing alloy, the standing time of the screw can be improved. A number of different hard facing alloys readily available in India have been tested as part of this work. The best results have been found with tungsten carbide, which is also the cheapest hard facing alloy in India. The standing time has been increased from four to 15 hours without pre-heating the material.



A general picture of the plant

The standing time can be further augmented by preheating the raw material. Pre-heating improves the performance by softening the biomass and reducing the load on the screw. In the second phase of the test programme, a thermic fluid pre-heater has been installed, to raise the material temperature to 120 to 140°C in order to study the effect on the power consumption and standing time of the screw against wear. Reductions in power consumption between 30 and 40% have been found. Also the pick-up characteristic of the material improves, giving a smoother output.

The feed temperature is not critical for the production of good quality briquettes.

Emphasis in the test programme continues on improving the life of the screw. This will be followed by optimisation of the briquetting process and obtaining performance data on other potential feedstocks, such as bagasse pith and coffee husk.

5. Implementation strategy

In a parallel component of the project, the Tata Energy Research Institute (TERI) is carrying out a financial analysis of briquetting technology and assessing the market for briquettes to help design a better strategy for the wider dissemination of both the technology and briquettes as a fuel. Initial results have shown that a general financial analysis is difficult since results are very site-specific. This problem is compounded in India, due to the size of the country giving such diverse geographical areas and different operating climates which lead to wide variations in raw material prices and transport costs.

The key factors for the consumer are the price of the briquettes and their relative performance compared to other available fuels. Briquettes can be a major competitor to, and readily substitute for, coal, wood or lignite. It would appear that Rs. 1,200 to 1,400 ($1 = Rs. 30 approx.) per tonne is the acceptable cost at present. This sets the target for the development of the technology to reduce costs to a level which will allow briquettes to penetrate the fuel market in India.

The cost of the briquette depends almost entirely on the life of the screw instead of other costs such as labour, energy (used to operate the machine) and transport. This confirms the importance of increasing the life of the screw to decrease the cost of the briquettes.

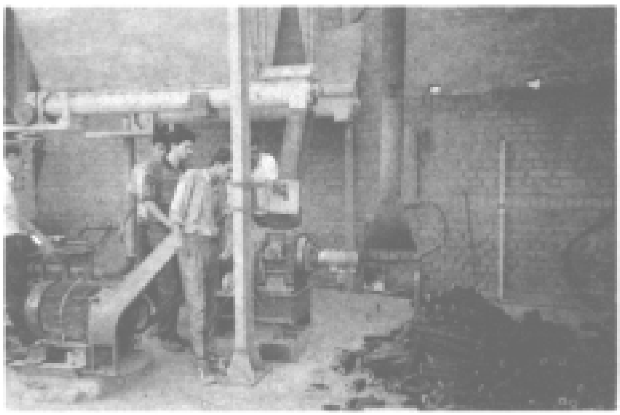
Table 2 shows some of the other major shortcomings of briquetting technology that have been identified as part of this study. These problems also have to be addressed if there is to be widespread acceptance of the process.

Table 2: Major shortcomings hindering the wider dissemination of briquetting technology

Financial	Selection of raw materials Site specific Seasonal (eg operation not possible during monsoon)
Technical	Production rate Maintenance procedures Wear cost Expertise
Users' acceptance	Related fuel market Demand patterns
Environmental	Dust/smoke emissions Competition with wood

6. Conclusions

A definite potential and demand for the briquetting tech-



A view of the screw press and the product obtained from the plant

nology and briquettes has been confirmed in India. Briquettes could penetrate the commercial fuel market in the short term with an appropriate marketing strategy. However, a number of problems of technical, social, environmental and economic nature have also been recognised which need to be addressed to achieve a wider dissemination of a more sustainable technology.

The price of briquettes and their fuel quality compared to other fuels have been determined as the most significant parameters for the consumer.

Screw extrusion has been identified as the most appropriate technology for the developing countries. The screw lifetime has been shown to be the key factor in reducing briquette production costs. Research, the initial results of which are reported here, to improve screw lifetime and the other main problem with the screw extruder, its high power consumption, are showing promising progress in achieving these aims. Results have shown that application of a suitable hard facing alloy to the surface of the screw increases the standing time significantly which has important implications for costs and continuity of production. Pre-heating the biomass has been shown to reduce power consumption between 30 and 40%. ■

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An integrated biogas/fodder project for small scale dairy farmers in Rusitu, Zimbabwe

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The Biomass Users' Network (BUN) is a South-led international non-governmental organisation with offices in Sao Paulo, Brazil (Head Office), Costa Rica, Thailand, and Zimbabwe (regional offices), a liaison office in Washington as well as an information and skills office in London.

The Africa Regional Office in Harare, Zimbabwe is involved in numerous biomass related projects.

One project which is being implemented with resettled small-scale dairy farmers combines biogas plants, cassava for fodder, and the introduction of Jatropha curcas (physic nut) hedges for revegetation and the production of oil. The plant belongs to the family of Euphorbiaceae and is related to the castor oil plant (GTZ, 1993).

The project area, the Rusitu Small Scale Dairy Resettlement Scheme, is on the eastern border of Zimbabwe with Mozambique (see Fig. 1). The small-scale dairy farmers who are allowed to resettle there are screened for experience and ability, and allocated 4 hectares (ha) each on undulating terrain. Of this, 2.5 ha is used for growing fodder, 1 ha for own crops, and 0.5 ha for buildings (ARDA, 1993). Most of the land is allocated to fodder production because the dairy cattle are zero-grazed. The 4 ha plots are all subdivisions of one large tract of land. The households on adjacent plots are anything from about

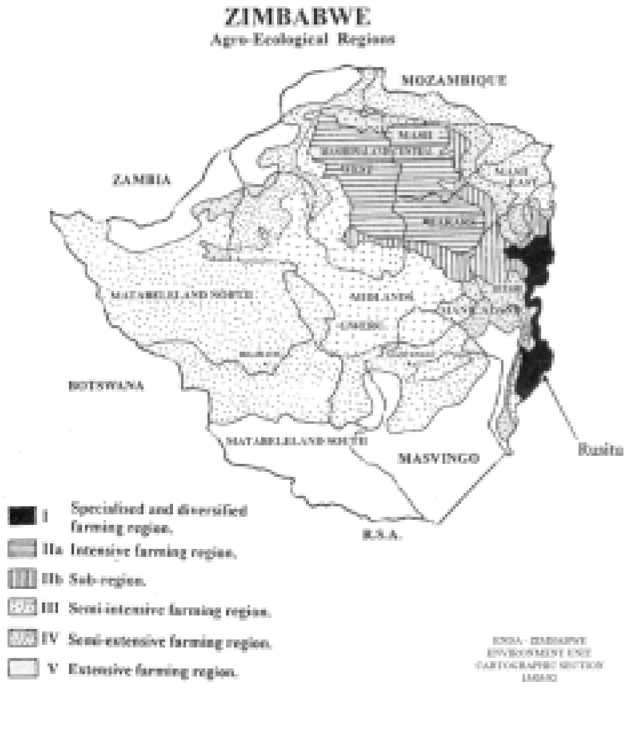

Fig 1. Agroecological regions of Zimbabwe (ENDA-Zimbabwe, 1992). Rusitu is in region 1, see map key for description.