Reprinted from Urja (Indian Journal of Energy) June, 1982

Economics of Wood Energy in India

L A PATEL*
B MISHRA**
L L PATEL***

This paper presents a model for the development of wood energy in India. According to the model, energy-rich trees are grown on the land spared by villages and also on land presently lying idle on both sides of the railway/road route. This scheme makes the best possible use of land, avoids future mishaps, and makes wood available to all sections and citizens. The paper then presents an economic analysis of the proposed model. Necessary algebraic expressions are derived, and a graphic presentation thereof is given, whereby it is possible to estimate the product thresholds and profitability ranges under different conditions.

The availability of energy is a vital factor[1] in the process of growth and development of any civilisation. In India, the oil crisis has rendered the sailing of domestic, transport, agricultural, and industrial sectors completely chaotic. It is, therefore, being stressed that the utilisation of renewable energy sources should be enhanced[2] to the extent possible so as to lower India's dependence on oil. Wood as a renewable energy source has drawn the attention of many scientists. Considerable research and development activities[3-6] have already occurred and are presently in progress in the field of technical feasibilities of advanced-type or modified-simple-type technologies to use wood as an energy source. Not enough attention has, however, been paid to the question of economic feasibilities[7] of such substitutes. Since this question is very vital from the point of view of integrated energy systems and energy planning, it is worth considering. The present paper reports the conclusions of a modest investigation carried out by the authors in the direction of economic feasibility study of wood as an energy source.

Section 2 proposes a model for the development of wood energy in India so as to make the best possible use of land, avoid future mishaps, and make wood available to all sections and citizens. Section 3 outlines the principles of utilisation of wood energy. Section 4 presents an economic analysis of the proposed model, and points out the conditions under which wood energy utilisation may become cost effective.

Model for Development

The geographical area[8] of India is 329 million hectares, out of which the forest area is 67 million hectares. Indian forests are extensively used for materials; hence their use for energy will lead to the scarcity of materials produced by them. Indian forests are localised and dense; hence their use for energy will involve high costs of harvesting and transportation. From these two materialistic viewpoints, it is not at all advisable to use Indian forests for energy.

* Centre of Energy Studies, IIT, New Delhi
** Malviya Inst of Petroleum Exploration, Dehradun
*** Lap Lab, Sardhab, Gandhinagar.

There are 0.5 million villages[8] in India. Suppose that each village can, on the average, contribute x hectares of land for the purpose of growing energy-rich trees. Further suppose that each tree requires a land-area of about 4 square metres. Thus the number N_1 of energy-rich trees that can be grown on the land contributed by villages in India is given by

$N_1 = 0.5$ million $\times x$ hectares $\div$ 4 square metres
$= 1250\ x$ millions.

The railway route[8] in India is 0.06 million kilometres in length, and the road route is 1.38 million kilometres in length. Out of this total route length, approximately 0.70 million kilometres of route length are such that one row of energy-rich trees can be grown on each side of the route. Suppose that a separation of about 4 metres required between two consecutive energy-rich trees of the same row. Thus the number N_2 of energy-rich trees that can be grown on the barren land along the railway/road route in India is given by

$N_2 = 0.70$ million kilometres $\times 2 \div 4$ metres
$= 350$ millions.

Neglecting energy-rich trees scattered elsewhere in India, the number N of energy-rich trees that can be grown in India is given by

$N = N_1 + N_2$
$(1250\ x + 350)$ millions.

The nature of energy-rich trees would vary from region to region. It is, therefore, reasonable to assume that (i) an average energy-rich tree in India can produce y tons of wood per year for 10 years, and (ii) the calorific value of the wood produced by an average energy-rich tree in India is 3.5 million kilocalories per ton. By using special wood-fired stoves, the wood obtained from energy-rich trees can be burnt at an average efficiency of 50 per cent. Thus, the energy obtainable from the wood produced by the aforementioned energy-rich trees is given by

$E = N \times y$ ton/year $\times 3.5$ million kilocalories/ton
$= (4375\ x + 1225)\ y$ million kilocalories/year.

The utilisation of the above-mentioned wood energy would lead to a reduction in the consumption of some other energy source. For the sake of comparison, the replaced energy source may be taken to be kerosene oil. The calorific value of kerosene oil is 10.0 million kilocalories per kilolitre. Therefore, the quantity of kerosene oil which can be replaced by the aforementioned wood is given by

$Q = E \div$ (10.0 million kilocalories/kilolitre)
$= (437.5x + 122.5)\ y$ kilolitres/year.

Principles of Utilisation

Wood energy [3-6] can be utilised in two different ways : (i) by combustion of 'wood oil' extracted from wood, and (ii) by combustion of wood. The technology of wood oil is not yet well established, and hence it is reasonable to ignore here the method of utilisation of wood energy by combustion of wood oil.

The equipment [6] indispensable in the method of utilisation of wood energy by combustion of wood is a 'wood stove'. The design of a wood stove is such that (i) the combustion of wood is complete in the sense that almost the entire amount of energy contained in the wood is extracted, (ii) the combustion of wood is controllable in the sense that its speed can be lowered or enhanced as per requirement, (iii) air pollution is very little, and (iv) ash is separated out. The design of a wood stove for an industrial process (or for a thermal power plant) includes several automatic-operation systems. The size and exact construction of a wood stove depend on various factors. However, for the purpose of an economic analysis, it is reasonable to consider an average wood stove which can be used to burn 5 tons of wood per year for 5 years.

The method of utilisation [6] of wood energy by combustion of wood involves the following operations : (1) cutting of wood from an energy tree, (2) drying of wood by keeping it in the sunlight for a few days, (3) sizing of dried wood into pieces readily acceptable for combustion, (4) storing of wood pieces as per supply and demand, (5) preparation for the commencement of combustion of wood, and (6) control of the flow of wood pieces into the wood stove being used for the combustion of wood.

Economic Analysis

Notation	*Item*	*Million rupees*
I_1	Initial planning	300
I_2	Initial popularisation of the wood energy utilisation	1000
I_3	Clearance of 0.5 x million hectares of the land spared by villages @ Rs. 4000/hectare	2000 x
I_4	Clearance of the barren land along 0.70 million kilometres of railway/road route @ Rs. 2000/kilometre	1400
I_5	Plantation of $(1250\,x+350)$ millions of energy-rich trees @ Rs. 10/tree	12500 x 4500
I_6	Cutting and drying of $[(1250\,x+350)\,y/4]$ millions of tons of wood @ Rs. 3/0/0 ton	93750 xy 26250 y
I	Capital investment $(I = I_1 + I_2 + I_3 + I_4 + I_5 + I_6)$	93750 xy 14500 x 26250 y 6200
H_1	Annual interest on the capital investment @ 12.5 per cent $(H_1 = I/8)$	11718.75 xy 1812.5 x 3281.5 y 775
H_2	Annual popularisation of the wood energy utilisation	100
H_3	Annual maintenance of the village-spared land @ 25 per cent $(H_3 = I_3/4)$	500 x
H_4	Annual maintenance of the barren land @ 40 per cent $(H_4 = I_4/2.5)$	560
H_5	Annual maintenance of energy rich trees @ 10 per cent $(H_5 = I_5/10)$	1250 x 350
H_6	Cutting and drying of $[(1250\,x+350)\,y]$ millions of tons of wood @ Rs. 300/ton $(H_6 = I_6 \times 4)$	375000 xy 105000
H^+	Annual expenditure without rounding off $(H^+ = H_1 + H_2 + H_3 + H_4 + H_5 + H_6)$	386718.75 xy 3562.5 x 108281.5 y 1785
H	Annual expenditure appropriately rounded off $(H \simeq H^+)$	387000 xy 3600 x 108000 y 1800
G	Annual gain : $[(437.5\,x + 122.5)\,y]$ kilolitres of replaced kerosene oil @ Rs. 1600/kilolitre	709000 xy 196000 y
F	**Annual profit** $(F + G - H)$	$+322000\,xy$ $-\ 3600\,x$ $+\ 88000\,y$ $-\ 1800$

The above analysis shows that :

$y_0(x)$ = Number of tons of wood required to be produced by an average energy-rich tree so as to have zero annual profit (as a function of the number of hectares of land being contributed by an average village)
$= (18\,x+9)/(1610\,x+440)$,

$y_+(x)$ = Number of tons of wood required to be produced by an average energy-rich tree so as to have an annual profit of Rs. 1000 millions (as a function of x)
$= (18\,x+14)/(1610\,x+440)$,

$y^-(x)$ = Number of tons of wood required to be produced by an average energy-rich tree so as to have an annual loss of Rs. 1000 millions (as a function of x)
$= (18\,x+4)/(1610\,x+440)$,

$I_0(x)$ = Millions of rupees of capital investment required for zero annual profit (as a function of x)
$= (93750\,x+26250)\,(18\,x+9)/(1610\,x+440) + (14500\,x+6200)$,

$I_+(x)$ = Millions of rupees of capital investment required for an annual profit of Rs. 1000 millions (as a function of x)
$= (93750\,x+26250)\,(18\,x+14)/(1610\,x+440) + (14500\,x+6200)$,

$I_-(x)$ = Millions of rupees of capital investment required for an annual loss of Rs. 1000 millions

(as a function of x)

$$=(93750\ x+26250)\ (18\,x+4)/(1610\,x+440)+(14500\,x+6200).$$

Figure 1 depicts the variation of y_0, y_+, y_-, I_0, I_+, I_- with x. From this figure, it is possible to estimate the product thresholds and profitability range under different conditions.

Acknowledgements

The authors are very grateful to Professor M.C. Chaturvedi and Professor M.S. Sodha for their valuable comments.

References

1. K.S. Parikh : 'Second India Series Energy' (McMillan New Delhi, 1976).

2. Planning Commission of the Government of India 'Report of the Working Group on Energy' (Planning Commission of the Government of India, New Delhi, 1972).

3. D.A. Tzillman, K.V. Sarkanan, L.L. Anderson : 'Fuels and Energy from Renewable Resources'.

4. D.E. Earl ; 'Forest Energy and Economic Development'.

5. C.C. Kemp, G.C. Czego : 'Energy Plantation'.

6. C.H. Stoner : 'Producing Your Own Power' (Rodale Press, Emmaus, 1974).

7. T.H. Ellis : 'Economic Analysis of Wood or Bark Fired Systems' (AD/A 052 208 NTIS, US Department of Commerce, Springfield, 1978).

8. Ministry of Information and Broadcasting of the Government of India : 'India 1980' (Publication Division of the Government of India, New Delhi 1980).