The Problem of Fuel Wood Energy Demand in Malawi with Reference to the Construction Industry

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Abstract

The problem of Energy demand in Malawi has to some extent affected the construction industry. Almost all burnt bricks in Malawi are produced on scove kilns and this is an inefficient process and consumes a lot of fuel wood. This demand has competed with the domestic demand with disastrous effects on the environment. This paper argues that while the construction industry has ready alternative, there is a remote chance to reduce the domestic wood fuel demand until government can exploit other sources of energy in the urban areas for domestic use.

The demand for burnt brick has contributed to the deforestation of Malawi. It is further argued that government should ban the use of burnt bricks and there would be a rapid growth of other brick substitutes that require very little energy to produce. The paper has outlined the basic facts of energy conversion scenarios from all available energy sources in Malawi. Conversion of wood to heat has been singled out as the least efficient and therefore recommends that the use of fuel wood for burning bricks should be discontinued while the conversion into charcoal should be checked. Other substitutes for the burnt brick should be explored and the paper has given a number of examples that would contribute to the reduction of the current large demand on wood fuel.

A Historical Perspective

One of the major construction materials in Malawi is timber. Construction timber can be classified as hardwood or softwood. From experience the hardwood timber has a higher density and grows more slowly than soft wood. The former is used as finishes in buildings and furniture. Traditionally hardwood was used as structural material in building construction. However, with the advent of colonialism hardwood was exploited for railway slippers between 1908 when the railway line reached the southern tip of Nsanje and 1935 when the Railway line finally reached Salima. Since that time hardwood has been under pressure due to clearing of land for farming, construction and for firewood.

Until 1989 softwood for construction in Malawi was imported from Canada. At that time government had grown mature pine trees in Zomba, Mulanje and Dedza mountains but for some unknown reasons the local pine was considered inferior compared to the Canadian pine. By 1989 government definitely had made a decision to discontinue ordering pine from Canada.

The decision to move the capital from Zomba to Lilongwe in 1973; stimulated a lot of housing projects. There was a big demand for hardwood for door frames, window frames and for veneers for use as internal finishes. Mbawa, (*Khaya, nyasika*) and Mlombwa (*Pterocarpus angolensis*) were the most exploited. In the course of time most of the natural trees that were considered suitable for timber were depleted from the forests except a few protected mbawa in urban areas of Zomba and Blantyre.

When government moved to Lilongwe in 1973; there was foresight to plant *Pinus patula* in Chikangawa so that the country could have a pulp industry. This was a big project. Unfortunately or fortunately somewhere along the way there was an objection from the World Bank who were to be the financiers of that pulp industry. This objection was centred on the likelihood of the industry polluting the lake since the affluent was to be drained into the lake. This is the forest that has now served and saved the construction industry to date as a source of construction softwood.

Along this road to development was another subtle area of demand for natural wood. The construction industry in Malawi mostly uses burnt bricks that are prepared in scove kilns because concrete blocks are more expensive than these bricks. The high cost of concrete blocks is due to the cement content and cement is relatively very expensive as a component. Although there were a number of fast growing exotic woods that were being planted by government and were recommended for firewood such as Blue gums (*Euclayptus camadunsis/glandis/ terecornis)*, Gmelina (*Gmelina arborea)* and Pine (*Pinus patula*) partly due to their rapid growth rates. (1)(7)(13) People's own intuition led them to believe that there was more energy in indigenous hardwoods than there was in all these exotics. That conjecture is actually a fact (1), further the natural hardwoods were available in the countryside at almost no cost. This was the mistake that was made and continues to be and that action has also contributed to the deforestation in this country.

Fuel Wood Energy Content

The content of energy in wood is generally directly proportional to its density (8). Energy content of a few species are shown on table 1 for ease of comparison.

Table 1. Calorific Values(CV) and Growth Rates of Four common wood Types.

Common Name	**Biological Name**	**Energy Content MJ/ kg**	**Growth rate m^3/ ha**
Blue gum	*Eucalyptus camadulensis*	19.4	187.2
Gmelina	*Gmelina arborea*	18	73.5
Pine	*Pinus patula*	17.8	10-30
Indegenous hard woods	*Brachystagia species*	21.5	3.51
Mean CV		**19.2**	

The demand for burnt bricks in the construction industry has stimulated a huge demand for hardwood for burning the bricks. This demand is most severe in the peri-urban areas. However, in recent times wood fuel has become a business and suppliers have penetrated deep into the rural areas to cut most of the indigenous wood. The assessed number of households earning income from charcoal is currently estimated at 8.2% (2).

The author undertook a short research to find out how much is required to put one burnt brick until it is ready to be used in construction. The investigation involved a study of some twelve kilns in Likuni area in Lilongwe. The input information was reported at a workshop convened by government (3) but has been abstracted on table 2.

Government has recognised the importance of wood energy. To that end government has enacted a special Forestry Act [11]. The assessment for resources in 2003 has listed the country's energy sources as the following Biomass 93%, liquid funds 3.5% Electricity 2.3% coal 1% and Renewable 0.2% by 1990 (16).

Table 2. Surveyed Brick Kilns in Likuni Area in Lilongwe (1994).

Kiln No.	Wood Type	Calorific Value MJ/kg	Number of Bricks X 10^3 *(f)*	Wt. Wood used X 10^3 kg	Calculated Energy X 10^3 MJ *(x)*	Energy Rqd. Per Brick MJ
1	Brachystagia	21.5	97.4	26	559	5.7
2	Gmelina	18	80	20	360	4.5
3	Eucalyptus	19.4	33	14	272	8.2
4	Eucalyptus	19.4	42	18	349	8.3
5	Brachystagia	19.4	35	18	349	10.0
6	Eucalyptus	19.4	20	14	272	13.6
7	Eucal. & Gm.	18.7	36	21	393	10.9
8	Brachystagia	21.5	75	20	430	5.7
9	Brachystagia	21.5	75	25	538	7.2
10	Eucalyptus	19.47	50	30	584	11.7
11	Eucalyptus	19.4	50	30	582	11.6
12	Eucalyptus	19.4	50	31	601	12.0
13	Brachystagia	21.5	40	24	516	12.9

The weighted mean calorific value was calculated from these values in the normal manner

$$\bar{X} = \frac{\sum fX}{\sum f} = 8.5 \qquad (1)$$

Where $\bar{X}$ is the weighted mean value and X is the product of the calorific value of each type of wood and the mass of that species.

In this case the weighted mean energy required to fire one brick was found to be 8.5 MJ. This agrees with what is reported in reference [2] that 1000 bricks require 0.7 tonnes of firewood. However, the variation from 5.7 – 12.9 MJ per brick can be explained by the fact that there is no agreed criterion for a burnt brick. The bricks that are considered ready range from under burnt to over burnt bricks.

The forest cover for Malawi was 34% in 1984 but this has been reduced to 26% in 2004. Most of the demand pressure comes from land clearing for Agricultural use and fuel wood. Fuel wood consumption per capital in Malawi is now at $2m^3$.[5] This is an increase from $1.4m^3$ reported in 1984 [11] Generally the rate of deforestation has increased from 24,500 hectares per year in 1984 as estimated for 1990 by the energy studies unit [6], to 50,000 hectares per year in 2004 [5]. While wood clearings for farming and wood fuel are problems that would require high investment solutions, brick burning using wood fuel is a preventable activity. Table 3; shows levels of energy consumption for Malawi and compares her position with other countries within the region (14).

Table 3. Energy Consumption of Malawi and the Neighbouring Countries.

Country	**Traditional Fuel Consumption (% Of Total Energy Requirement)**	**Electricity Per Capital Consumption kw-h**	
		1980	2002
Kenya	64.9	109	155
Mozambique	80.3	364	378
Tanzania	82.6	41	83
Zambia	87.3	1125	603
Zimbabwe	66.2	1020	981
Malawi	85	66	80

The energy content of wood E_O can be calculated as:

$$E_O = \left\{ \left[(\kappa_1 m_1) + \left(\kappa_2 \; m_2 \right) \right] - (\kappa_3 m_3) \right\} - (1 - \mathrm{m}_4) \qquad (2)$$

Where κ_1 is calorific value constant for wood

m_1 is the mass fraction of hydrogen in dry ash-free wood

κ_3 is the calorific value carbon in dry ash-free wood

κ_2 is the calorific value constant for hydrogen

m_2 is the mass fraction constant for oxygen.

m_3 is the mass fraction of oxygen in dry ash-free wood.

m_4 is the mass fraction of ash in dry wood.

However, the current methods of converting wood fuel to end use energy are quite inefficient. Under controlled condition (9) it is reported that 34.4% thermal conversion efficiency can be achieved with an insulated oven while 29.9% can be achieved with an un insulated oven. For wood conversion to charcoal under expert supervision efficiencies of up to 22% were achieved while efficiencies of 14% are common. Generally speaking, wood thermal conversion should be discouraged where there are better and environmentally friendly alternatives. If E_u is the useful energy while obtained and E_w is the wasted energy it can be shown that the end use efficiency (η_u) can be obtained from the simple relationship.

$$\eta_u = 1 - \left(E_w / E_u \right) \qquad (3)$$

For charcoal E_w is a sum of two stages. One stage E_{w-c}; energy lost in converting to charcoal and the second stage E_{c-u} energy lost in the process of converting charcoal to end use energy in a sequential order such that

$$E_w = E_{w-c} + E_{c-u} \qquad (4)$$

If the intermediate thermal conversion efficiencies were to be represented by η_{w-c} and η_{c-u} respectively, it can be shown that numerically $\eta_{w-c} + \eta_{c-u} = \eta_u$ depending on the conversion methods and equipment used bearing in mind the first law of thermodynamics.

The need to convert wood to charcoal is principally to reduce the weight of the fuel and to have the convenience of storing it better than fuel wood. Table 4 shows the constituents as products of thermal conversion of wood by weight. This confirms that the bulk of the weight that is driven out of the wood during the first stage to turn the wood to charcoal is some carbon as $C0_2$ and a lot of water (H_20). The final product is charcoal that is lighter and rich in carbon.

Table 4. Constituents Of A Typical Combustion Of Dry Wood

Element	**% (weight)**
Carbon	51.2
Hydrogen	5.4
Oxygen	43.4
Ash	0.9

Other Alternative Solutions to Reduce Demand on Wood fuel

Table 3 shows clearly that each of the countries' energy demand has a traditional fuel component of over 60%. The traditional energy components include the use of fossil fuels and wood energy. Some electricity in other countries may come from thermal power stations but that fraction is very insignificant. In Malawi all the electricity in generated from hydropower stations.

If consideration is taken of the size of a country and the population, Malawi being the least industrialised as evidenced from the energy consumption, makes its dependence on traditional fuels very critical. The sooner the pressure of wood energy is reduced especially in the urban areas the better will be the future of the country. If that were done the construction industry would have more wood at its disposal, both uses as timber and as poles.

Energy Alternative 1: Coal

Malawi has a lot of coal but it is not being exploited to the best advantage of the country. The Department of Geological Survey has undertaken a lot of investigations and has confirmed several coal deposits around the country [(4).]

Table 5. Reported Coal Resources of Probable resources metric tonnes (mt)

Name of Location	Confirmed Reserves $X10^6$ (mt)	Speculated Reserves $X10^6$ (mt)	Ash Content (%)	Sulphur Content (%)	Calorific Value Kcal/kg
Ngama	1.5	50	30.2	2.2	4708
Livingstonia	1.4	5	17	0.5	6800
Lufira	0.6	50	30.2	2.2	4708
Mwabvi	5.0	10	40	0.76	4173
North	0.5	170	32.4	0.6	4781
Rikuru	-	10	59.2	0.51	2746
Lengwe Nthalire	-	15	-	-	-
	9.0	**310**	**-**	**-**	**-**

Table 5; shows the coal resources in Malawi. It is further estimated that the total speculated reserves amount to 800 million tonnes. The distribution of this resource is mainly concentrated in the north but it would not be a big problem to distribute little coal by rail or by lake service to the urban parts of the country.

What is encouraging is that the quality of the coal is relatively high compared to most coals available on the continent. This coal can be used to supply the acute energy in the urban areas where charcoal and fuel wood are major sources of fuel. It is estimated that the urban dweller in Malawi consumes 3 times the volume of wood fuel compared to the rural dweller [(14)]. This is where coal as an alternative can save the country from deforestation.

The thermal conversion equation for coal is the same as that in (3). However, charcoal would only be converted once direct from coal to end use energy. To compute the relative energy content in coal in Mega Joules, the column five in table 5; must be converted by a factor of 4.186. It can be observed that the coal at Livingstonia has the highest calorific value and for domestic use the cooking ware would need to be cast iron or earthen pots. Coal is harder, denser and relatively more resistant to rough handling than charcoal. Therefore for any given volume of load there would be more energy than in charcoal.

Energy Alternative 2: Direct Solar Energy

The solar irradiation in Malawi averages at 21 $MJ/m^2/Day$ in the low-lying areas [(16) (17)]. The solar radiation has three components namely Direct, Diffuse and Reflected. The reflected component mainly consists of long wave radiation and is a small component comprising less than 5% of the total energy incident on a unit surface and highest in low lying land areas due to reflections from the mountains. The diffuse component is about a third of the direct component and increases during cloudy and overcast days.

For a normal bath a person requires 35 litres of water. To raise water temperature from 20^0C to 40^0C, which is the established bath water temperature [(14)], 2.93 MJ are required. It is reported that the average urban household in Malawi consists of five persons. The daily energy demand for a hot water bath for such a household would be 14.65 MJ. If energy required for cooking is added to this figure the end use energy requirement comes to 25 MJ per household per day and that is what is causing deforestation and depriving the construction industry of a very useful resource. If this energy were to be drawn from an electric immersion heater, which is normally 90% efficient, the amount of energy to be bought from the national grid would be 28MJ. On the other hand if this energy were to be drawn from wood fuel, which has a common thermal conversion efficiency of 20%, the gross energy required would be 140 MJ. This translates to 6.5kg of Brachystagia wood or 7.8kg of Gmelina or indeed 7.9kg of pine per day. This errand alone accounts for $1m^3$ per capita. .

Heating water for baths can be achieved by the use of solar water heaters. Solar water heaters work with both direct and diffuse components and so do photovoltaic devices. However, reflectors do not work very well with the diffuse component. The solar water heaters can be used for all water heating both for baths and for preheating water for cooking in urban areas. Solar cookers although not as efficient as solar water heaters can be made by ordinary house wives and the author has participated in a programme to teach women how to make these in Lilongwe and Mchinji districts and they are working. Solar water heaters have been used in several hospitals the latest being Nkhota-kota. Where the author has used evacuated tube solar water heaters.

Compressed Soil Brick as Alternative to the Burnt Brick

The other alternative is to popularise the use of Stabilised Soil Blocks (SSBs) as a construction material. There is very little or no energy required manufacturing a Stabilised Soil Block. What is required is local selected earth mixed with a minimum amount of 10% cement and compressed at high pressure and cured under a shade where the blocks are allowed to lose moisture slowly until the residual water content is about 10-12%.

The author has used these on government buildings. The minimum crusting strength observed was 3.8 N/mm^2 while the highest was 5.8 N/mm^2. In contrast a grade 3 brick as required by the Malawi Bureau of Standards must have a mean crushing strength of 3-3.5 N/mm^2[(18)]. In other countries these bricks are required to have a minimum of 3.5 N/mm^2[(19).] . However, the SSB has a few disadvantages. One of those disadvantages is its property to dissolve in water. Appropriate detailing in the design can check this weakness.

Table 6. Outlines comparative costs of several building materials in common use. Note the difference in the prices. The SSB is the cheapest alternative. The concrete block is another alternative. However, the cost of cement puts this alternative at a level where it becomes unaffordable.

Table 6. The Stabilised Soil Block Compared With Other Alternatives.

	Description	Rates MK/m^2	Cost above lowest option %
1.	SSBs 140mm thick plastered and painted one side, brick sealer other side.	1,600.00	0
2.	SSBs 140mm thick strengthened; plastered and painted one side, brick sealer the other side.	1,700.00	6%
3.	Standard 230mm thick brick wall plastered and painted internally and pointed fair face externally with brick sealer.	2,000.00	25%
4.	Standard 230mm thick brick wall plastered and painted both sides.	2,200.00	38%
5.	Hollow Cement Sand blocks (2.5N/mm^2); 150mm thick, plastered and painted both sides.	1,960.00	23%
6.	Hollow Cement sand blocks (2.5N/mm^2); 200mm thick, plastered and painted both sides.	2,620.00	64%

(Abstracted from Reference 19) *Current currency equivalent 1USD=MK126*

Conclusion

The demand for wood for the construction industry is in direct competition with the demand for wood fuel. The highest demand for wood in the urban areas is wood fuel. If only government can popularise the use of coal most of the demand in urban areas would be reduced. On the other hand government must certainly support the use of SSBs. The SSBs are produced on site and therefore reduces cost of the transportation of the material to site. Government should take the lead and the private sector should follow. In the course of time there would be enough timber for the construction industry and the environment would be spared of deforestation. Government should also encourage the exploitation of coal as an energy source for a long-term solution to the urban energy demand. The use of burnt bricks using wood fuel should completely be discouraged. However, it would not be prudent to ban the use of burnt bricks because these will be in demand by those who can afford them. If burnt bricks were to be used they have to be burnt using coal.

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