Section 1| Unit 3 | Energy Balance

An energy balance generally takes the form of an accounting table that presents a complete picture of the flow of energy from source, through conversion, to final use. In its most general statement the balance captures, for each energy form, the general relationship

Domestic Production + Imports – Exports ± Stock Changes - Conversion Inputs + Conversion Outputs = Consumption.

The standard format is illustrated in Table below for wood and charcoal. Starting from the bottom of the table, we note household consumption of wood and charcoal of 400 and 120, respectively. (The question of appropriate units is discussed below) The 120 units of charcoal are produced by conversion from wood. If the efficiency of that conversion is 0.2, then 600 units of wood must be used to produce the 120 units of charcoal.

TABLE 1

The Standard Format[1]

	Wood	Charcoal
Domestic Production	1,000	
Import	0	
Exports	0	
Conversion	1,000	0
- input	-600	
+ output		120
Final Consumption	400	120
Industry		
Transport		
Households	400	120

Thus, in the conversion section of the table we see -600 units of wood (as input) and 120 units of charcoal (as output). Therefore, it follows that 1,000 units of wood must be supplied to meet the charcoal conversion and direct wood consumption demands. Since in this case there are neither imports nor exports, domestic production is also 1,000.

1. Units

Although such energy balances can be displayed in the form of the actual units of measurement (such as kWh of electricity, tonnes of coal, barrels of oil), for a number of reasons it is desirable to use a single unit. Since one of the most useful functions of such balances is to gauge the potential for fuel substitution, the use of an energy unit would seem indicated, such as joules (in the metric system) or British thermal units (Btu) in the British system. On the other hand, to the extent that the key focus in almost all developing countries is oil and the degree to which it can be replaced by other energy forms, there is some merit to the use of a so called "oil replacement unit" expressed in either tons or barrels. Indeed, the use of the "ton oil equivalent" (toe) as a basis for energy balances is now the general convention adopted by most countries, as well as by man international bodies, such as the World Bank and OECD.T In some countries, other units still prevail for historical reasons. For example, India uses a coal replacement value.[2]

However there remains the issue of how a ton of coal, for example, is to be converted into a "ton oil equivalent." The basis for conversion is the energy content of each fuel and, hence, the toe must itself be defined in terms of some quantity of energy. Absent some particular reason to the contrary, the toe should be defined as being equal to 10.2 million kilocalories (kcal) (the definition used by the Energy Department of the World Bank).[3]

The calorific values of the fuels encountered in a particular country must, of course, be evaluated on a case-by-case basis. The energy content of coal in particular may vary quite widely; metallurgical coal traded internationally may have a typical energy content of 6 million kcal per tonne, for example, while some lignite may be as low as 1 million kcal per tonne. Similarly, the energy value of crude and fuel oils varies considerably from country to country, according to the specific characteristics.[4] Thus the conversion values should be taken only as indicative; they must be refined for any particular application.

2. The Treatment of Electricity

Electricity presents a number of problems because a number of different ways of expressing its energy equivalence are possible: as its actual thermal energy equivalent (1 kWh = 3,412 Btu, or 860 kcal), or as the amount of thermal energy that must be consumed to generate one unit of electricity, which is typically 3 to 4 times this value (since the conversion efficiencies lie typically in the range 0.25 to 0.3). Moreover, on the supply side, how does one express the thermal equivalent of hydroelectricity?

The general convention is as follows. On the demand side, a kWh of electricity is measured in terms of its direct thermal equivalent, 3,412 Btu per kWh or 860 kcal per kWh. Generation is similarly expressed in terms of the direct equivalent. The difference between the two is then equal to the actual thermal losses in transmission and distribution. On the supply side, we enter the thermal energy equivalent of whatever fuel is used to generate electricity. In the case of non-thermal fuels, such as hydropower, the general convention is to use thermal equivalent. The number shown in the energy balance table for hydropower indicates the number of tons of oil equivalent it replaces. That, of course, raises the question, in a real system, of which thermal replacement value to use: the most efficient plant, the least efficient plant, the present average of all plants, or the average of all plants expected in some future year.

To facilitate cross-country comparison, the international agencies use yet a further definition, namely, the theoretical upper limit of thermal electricity generation efficiency of 34% (which translates to 4,000 kWh per tonne oil equivalent) [5]. The disadvantage of using this upper bound is that it tends to understate the contribution of hydroelectricity in a real system; in drought years the thermal plants that are used to make up the difference tend to be the less efficient peaking units that are pressed into immediate and base-load use. Thus the choice of unit for hydroelectricity is very much a matter of judgement. In a country where a great deal of additional hydropower potential is possible, the most appropriate unit may well be the 34% upper bound, since new oil-fired base-load power plants they would replace would likely be fairly efficient. On the other hand, in a country where the hydro resources are largely exploited, and where the major focus for policy in regard to hydro is the operational use of existing facilities, a value representative of the existing system would be indicated. In any event, the important point is simply that whatever assumption is in fact utilized be clearly stated as a footnote to the Energy balance table.

Table 2 illustrates these consumption is 27-31 GWh, which converts to 320 ktoe (thousand ton oil equivalent). Generation is 34.39 GWh, with 20% loss in transmission and distribution. Assuming that 50% of the generation is from fuel Oil and 50% from hydroelectricity, and the efficiency of fuel oil generation is 25%, then 800 ktoe of fuel oil inputs are required. If we use the same 25% conversion efficiency for hydroelectricity, we see that hydroelectricity displaces 800 ktoe of fuel.

TABLE 2

The Treatment Of Electricity[a]

	Hydro	Fuel Oil	Electricity
Domestic Production	800	800	
Imports		800	
Total Availability	800	800	
Conversion			
- inputs	800	800	
+ outputs			400 (34.39)[c]
T&D Losses[b]			-80
Consumption			320 (27.51)

[a] Units: 1,000 toe; GWh in paranthesis.
[b] T&D Losses = 20% of generation
[c] Total Consumption

3. The Treatment of Non-Commercial Energy

Noncommercial energy forms pose special problems. Conceptually the most tractable are non-commercial fuels such as agricultural wastes and fuel wood, which while not commercially traded are at least amenable to quantification in thermal equivalents given rudimentary survey data. Much more difficult are animal and human energy, which are important components of the energy sector in some countries. Clearly the 600 elephants still employed in the timber and port industries in Burma or the countless rickshaw operators of Bangladesh should not be neglected, especially in situations where modern, commercially traded energy (generally some form of petroleum product) is beginning to replace such traditional sources. Indeed, increasing agricultural productivity by the introduction of modern technology (diesel tractors, diesel or electric irrigation pumps, for example), is often in direct conflict with decreasing oil imports.

The importance of fuel wood, bagasse, and agricultural wastes is illustrated below. In many developing countries these account for over 90% of the total primary energy consumption.

	% of Total Primary Energy as Fuelwood, Bagasse, etc.
Malawi	92
Ethiopia	87
Rwanda	99
Haiti	79
Dominican Republic	45
Fiji	57
Sri Lanka	55

Some Examples

Table 3 shows the 1980 energy balance for Malawi. Here hydro is converted to a thermal equivalent using an efficiency of 31.3% (or 10,250 Btu/kWh). Note also that fuel wood and biomass account for some 92% of the total primary energy, typical of many small, low-income developing countries in Africa. Table 5.2, in Chapter 5, illustrates the energy balance for Sri Lanka, where fuel wood and biomass account for only 55% of the primary energy requirement.

Energy Balance, 1980

Malawi ktoe

	Petroleum Products	Coal	Hydro	Electricity	Total Commercial Energy	Fuelwood	Biomass	Total
Primary Supply								
Production	-	-	36.1	-	66.1	3029	83.4	3178.5
Imports	148.7	31.2	-	-	179.9	-	-	179.9
Exports	-	-	-	5.1	-	-	-	-
Total	148.7	31.2	36.1	5.1	179.9	3029	83.4	3358.4
Transformation								
Power Generation	-1.3	-	-36.1	37.4				
Total Supplies	147.4	31.2	-	32.3	210.9	3029.0	83.4	3320.5
T&D Losses	-	-	-	-2.8				
Net Supply to Consumers	147.4	31.2	-	29.5	208.1	3029.0	83.4	3320.5
Final Consumption								
Industry	60.4	29.6	-	21.6	112.6	1527.0	83.4	1723.0
Transport	80.6	-	-	-	80.6	-	-	80.6
Commercial	0.1	1.6	-	3.2	4.9	9.0	-	13.9
Residential	6.3	-	-	4.7	11.0	1493.0	-	1504

The World Bank, 1982