1. Traditional Energy Systems

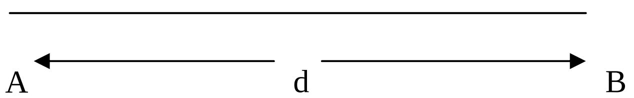
Introduction

For any activity involving other than muscle power a base energy and capital energy are required. This can be illustrated considering following two examples:

Consider a person walking between 2 points A B. the energy required will be Fd(=m*a*d) joules.

Now if the person uses a car the total energy will be Etranslational+Ecapital

Where Ecapital is the energy invested in making car.



Considering the example of energy required for ploughing a field:

When a tractor is used there energy spent on Ecapital. The various relative values can be tabulated as follows:

	Eplough KWh	Ecapital KWh	Energy efficiency
Traditional farming	6000	60	90%
Modern farming	6000	60000	10%

From above it is clear that though the energy efficiency for traditional farming is high the time required for modern farming is less.

Sources

The working speed for most draught animals is about 1 metre/second (3.6 km/h, 2 mph). A bull consumes about 3.3 Joules for each Joule of work. There are limitations on the performance of animals, such as sensitivity to food supply, getting sick etc.

Sustainable power of individual animals in good condition							
Animal	**Typical weight kN (kgf)**	**Pull-weight ratio**	**Typical pull N (kgf)**	**Typical working speed m/s**	**Power output W**	**Working hours per day**	**Energy output per day MJ**
Ox	4.5(450)	0.11	500(50)	0.9	450	6	10
Buffalo	5.5 (50)	0.12	650 (65)	0.8	520	5	9.5

Horse	4.0 (400)	0.13	500 (50)	1.0	500	10	18
Donkey	1.5 (150)	0.13	200 (20)	1.0	200	4	3
Mule	3.0 (300)	0.13	400 (40)	1.0	400	6	8.5
Camel	5.0 (500)	0.13	650 (65)	1.0	650	6	14
Note: For animals of different weight the power output and energy output per day may be adjusted proportionately Source: Tools for Agriculture, 1992							

http://www.fao.org/sd/EGdirect/EGan0006.htm

Animal	Force Exerted (lbs.)	Velocity (ft/sec)	Power (ft-lbs/sec)	Standard Horsepower	Force Exerted (N.)	Velocity (m/s)	Power (W)
draft horse	120	3.6	432	0.864	535	1.1	587
ox	120	2.4	288	0.576	535	0.7	391
mule	60	3.6	216	0.432	267	1.1	293
donkey	30	3.6	108	0.216	134	1.1	147
man	18	2.5	45	0.090	80	0.8	61

http://www2.sjsu.edu/faculty/watkins/animalpower.htm Metric conversion by Tim Lovett

For a hard day's work the horse reigns supreme, delivering 500W for 10 hours. The ox is known for its compliance and is less fussy about food - a good choice for the less demanding applications. The camel has the highest power output. Forget the donkey.
http://geoimages.berkeley.edu/GeoImages/Powell/Afghan/100.html
Camel powered pump in Afghanistan: For millenia waterwheels have been used to lift water for irrigation and domestic use.
This camel keeps walking in a tight circle to turn an axle which powers the waterwheel.

http://private.addcom.de/asiaphoto/burma/bdia085.htm
An ox crushes peanuts on a tiny mill in Thailand. Note the two arms - one steering the animal at the neck, while the other takes the power from behind the animal.

Power for common activities

Activities	Energy Consumed
Moving a body of unit mass with an acceleration $2m/s^2$ on a smooth horizontal plane	$555.56x\ 10^{-6}$ Whr/kg/m
Moving a body of unit mass with an acceleration $2m/s^2$ on a horizontal plane with coefficient of friction μ=0.2	$1100x10^{-6}$ Whr/kg/m
Moving a body of unit mass with uniform velocity on a horizontal	$544x10^{-6}$

plane with coefficient of friction μ=0.2	Whr/kg/m
Lifting a body of unit mass by unit height	2722×10^{-6} Whr/kg/m
Energy required for rotating a disc of J=2kg-m^2 with an angular acceleration α=2 rad/sec^2 per unit radian	1111×10^{-6} Whr
Energy required to raise the temperature of unit mass of water from 25^0 to 75^0	58.05 Whr/kg
Energy required to deliver water from a horizontal pipe with a delivery rate of 0.1lt/sec at a pressure of 20N/m^2	555.56x 10^{-6} Whr/kg/m
Energy required to move a body up an inclined plane inclined at an angle 45^o with an acceleration of 2m/s^2 with a frictional coefficient of μ=0.2	2863×10^{-6} Whr/kg/m
<u>Energy required for physical activities of human being (M=68kg)</u>	
Walking at a speed of 7 km/hr for a time of 1hr	464×10^{-3} Whr
Running at a speed of 10 km/hr for a time of 1hr	812.7×10^{-3} Whr
Cycling at a speed of 16 km/hr for a time of 1hr	510.8×10^{-3} Whr
Swimming at a speed of 2.4 km/hr for a time of 1hr	557.33×10^{-3} Whr
<u>Energy Storage</u>	
Typical rechargeable batteries	40-100 Wh/kg
Electrochemical capacitor	5-15 Whr/kg
Spring	0.1-0.3 Whr/kg

Reference:

1. www.brainmac.demon.co.uk
2. www.spi.auburn.edu\prospector