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Energy management in crop production

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ABSTRACT

In India, agriculture not only provides food for all, but also employment to 70% of the population, generates 40% of the national income and consumes about 10% of the commercial forms of energy. Crop cultivation requires application of both animate (bullock, human power) and inanimate (tractors, tillers etc.) forms of energy at different stages. Nutrients are provided through farmyard manure, chemical fertilizer or both. Pesticides are required to check or prevent pest attack. Irrigation is done either manually (manually and animal operated) or through diesel/ electric pumpsets (to lift ground water). To meet the basic food needs of our expanding human population, a productive sustainable agricultural system must become a major priority.The depletable resources are fossil fuels, which are non - renewable since the rate of their utilization far exceeds the rate at which they are formed.

Key words: Crop management, Energy management, Energy policies, Energy sources

Energy is a critical aspect of a national development process. It is expended in agricultural operation in food processing and transportation, in the production of fertilizers, pesticides, and farm equipments. It is necessary for industrial operations that provide jobs. It is required for cooking, for household lighting and heating, and for the construction and operation of the infrastructure needed for schools, health centres and water supply.

To obtain an understanding of energy matters, it is essential to convert energy rapidly to a common equivalent. The tonne of coal equivalent (t.c.e.) are such a unit and has been adopted by the United Nations (UN) bodies. Since the chemical composition of coal is not a fixed quantity, it is necessary to assume a representative figure. A commonly used value for the t.c.e. is 2.9×10^9 J or 29 GJ. Electricity is normally quoted in terms of kilowatt hours or units. It is helpful to know that a tonne of coal per year is approximately equivalent to an average power of 1 kW or 1 t.c.e. per year - 1kW.

Energy Sources

The energy sources can be classified in a number of ways based on the nature of their transaction, as commercial and non-commercial sources of energy. All energy resources, particularly the commercial ones, are natural. Coal, oil and nuclear sources constitute commercial sources, while firewood, biomass and animal dung constitute non- commercial sources. Also, the energy sources are classified based on animate and inanimate characteristics. Energy sources could also be classified as exhaustible / non - renewable or non - depletable / renewable resources. The distinguishing feature of an exhaustible resource is that, it gets exhausted when used as an input of a production process, and at the same time, its undisturbed role of growth is nil. That is, the temporal services provided by a given stock of an exhaustible resource are finite.

Further, based on conventionality in deriving energy, energy sources could be classified as conventional (coal, oil, hydro, nuclear, etc.) and non-conventional (solar, wind, tidal, geothermal, biogas, etc.) sources. They are also classified as primary types (coal, firewood) or secondary types (electricity). Energy in its primary form can be of different kinds. The main types are chemical (fossil fuels-coal, oil, natural gas, peat; biomass - wood, agricultural residues, etc.), potential (water at a certain height), kinetic (wind, waves), radiation (sun), heat (geothermal reservoirs, ocean thermal reservoirs) and nuclear (uranium). The primary form of energy must generally be converted into secondary or final forms of energy before it can be used. For instance, the potential energy of a waterfall (primary energy) is converted into electricity (secondary energy), which is transmitted and transformed to supply (final) energy to a factory, where it is converted into mechanical energy (useful energy) for productive operations.

Important types of secondary energy are electricity and mechanical energy. But chemical energy is also important as a secondary energy, for instance, refined oil products. Final energy is the energy that reaches the consumer. This

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can be electricity at a suitable voltage, or chemical energy in kerosene or batteries. Most of the energy sources are substitutable to each other due to the fact that some form of energy can be converted to other - such as coal to electricity, use of photo-electricity to drive a chemical reaction, wind energy to pump and store water that could be used to produce electricity when required, or solid biomass to produce liquid or gaseous fuels of higher calorific value. All forms are ultimately converted into heat. This gives rise to the inter-fuel substitution process with which an economy can substitute its abundantly available resources to the scarcely endowed one.

Classification of energy

On the basis of source, the energy can be classified as direct and indirect energy.

Direct source of energy

The direct sources of energy are those that release the energy directly-like man power, bullocks, stationary and mobile mechanical or electric power units, viz., diesel engines, electric motor, power tiller and tractors. The direct energy may be further classified as renewable and non-renewable sources of energy depending upon their replenishment.

Renewable direct sources of energy: In this category, the energy sources, which are direct in natural but can be subsequently replenished, are grouped. The energies which may fall in this group are human beings, animals, solar and wind energy, fuel wood, agricultural wastes9o etc.

Non-renewable direct sources of energy: In this category, direct energy sources which are not renewable (at least in near further say next 100 years) are classified. Coal and fossil fuels exemplify non-renewable direct sources of energy.

Indirect source of energy

The indirect sources of energy are those which do not release energy directly but release it by conversion process. Some energy is invested in producing indirect sources of energy. Seeds, manures (farmyard and poultry), chemicals, fertilizers and machinery can be classified under indirect sources of energy. Again, on the basis of their replenishment, these can be further classified into renewable and non-renewable indirect source of energy.

Renewable indirect source of energy: Seeds and manures can be termed as renewable indirect source of energy as they can be replenished in due course of time.

Non-renewable indirect source of energy: The energy sources that are not replenished come under non-renewable indirect sources of energy. Chemicals, fertilizers and machinery manufacturing are the non-renewable indirect sources of energy.

On the basis of comparative economic value the energy may be classified as commercial and non-commercial.

Commercial energy

The energy sources like petroleum products (diesel, petrol and kerosene oil) and electricity, which are capital intensive, exemplify commercial sources of energy. Considering the fact that most of the commercial sources are also non-renewable and to some extent are imported to India, efforts are made to conserve such sources of energy.

Non-commercial energy

Each and every energy source has some economic value. Some energy sources are available comparatively at low cost whereas others are capital intensive. The energy sources which are available cheaply are called non-commercial sources of energy whereas the ones which are capital intensive are called commercial energy sources.

Human labour and bullocks exemplify the category of non-commercial source of energy. Human labour and animals are readily available and can be used as a source of power directly. The commonly available and less expensive materials like fuel wood, twigs, leaves agro-wastes and animal dung, etc. are also classified as non-commercial sources of energy.

Energy input from various sources

Direct sources

The energy input of human labour and a pair of large bullocks (having a body weight of 450 kg) may be assumed to be 1.96 MJ / man-hr and 14.05 MJ / pair-hr, respectively. The specific fuel consumption of the mechanical power source (obtained from the test report) can be used to find energy inputs. The energy input of various direct sources of power is given in Table 1.

Indirect sources

The energy requirement in producing seeds, fertilizers, pesticides, weedicides, etc. is also given in Table 1.

Calculation of energy requirements for a field operation

The energy requirements for a particular field operation may be calculated as the summation of human, bullock and mechanical and / or electric energy consumed.

Operational costs for various power sources

Manual power: In case of human labour, the wages of an unskilled labour on the basis of hour or day (as prevailing in a particular locality) are charged.

Table 1. Equivalents for direct and indirect sources of energy

Particulars	Units	Equivalent energy (MJ)	Remarks
Inputs			
Human labour			
(a) Adult man	Man-hour	1.96	
(b) Woman	Woman-hour	1.57	1 Adult women = 0.8 adult man
(c) Child	Child-hour	0.98	1 Child = 0.5 adult man
Animals			
(a) Bullocks			
(i) Large	Pair-hour	14.05	Body weight above 450 kg
(ii) Medium	Pair-hour	10.10	Body weight 352-450 kg
(iii) Small	Pair-hour	8.07	Body weight < 350 kg
(b) He-buffalo	Pair-hour	15.15	He-buffalo=1.5 medium bullock
(c) Camel or horse	Animal-hour	10.10	Camel or horse = medium bullock pair
(d) Mules and other small animals	Animal-hr	4.04	Small animal = 0.4 medium bullock pair
Diesel	Litre	56.31	It includes the cost of lubricant
Petrol	Litre	48.23	
Electricity	KWh	11.93	
Machinery			
(a) Electric motor	kg	64.80	Distribute the weight of the machinery equally over the total life span of the machinery (in hours). Find the use of machinery (hours) for the particular operation in a crop.
(b) Prime movers other than electric motors (including self propelled machines)	kg	64.80	
(c) Farm machinery	kg	62.70	
Chemical fertilizers			
(i) N	kg	60.60	Estimate the quantity of nitrogen, P_2O_5 and K_2O in the chemical fertilizer. Then compute the amount of energy input from chemical fertilizer.
(ii) P_2O_5	kg	11.1	
(iii) K_2O	kg	6.7	
Farm Yard Manure	kg (dry mass)	0.3	
Chemicals			
(i) Superior chemicals	kg	120	Chemical requiring dilution at the time of application
(ii) Zinc sulphate	kg	20.9	
(iii) Inferior chemicals	kg	10.0	DDT, gypsum or any other chemicals not requiring dilution at the time of application
Seed			
(a) Output of crop production system and not processed			Same as that of output of crop production system
(b) Output of crop production system and is processed before using it for seed (e.g. potato, groundnut, cotton)			Add 1.5, 1.0 and 0.5 MJ / kg for potato, groundnut and other seed respectively to the equivalent energy of the product of crop production system
Output			
Main Product			
Cereal [wheat, maize, sorghum, bajra, barley, oats, paddy (not shelled rice)] Pulses, (Mash, moong, lentil, arhar, soybean, peas)	kg (dry mass)	14.7	The main output is grains

Table 1. *Continued...*

Particulars	Units	Equivalent energy (MJ)	Remarks
Oilseeds (such as cottonseed, groundnut pods (not shelled), sesame, rapeseed, mustard, linseed, sunflower)	kg (dry mass)	25.0	The main output is seed except for groundnut (where it is pod)
Sugarcane	kg (harvested mass)	5.3	
Vegetable			
Root or tuber vegetables			
(i) Higher food value: sweet potato, tapioca	kg	5.6	
(ii) Medium food value: potato, beet root, colacasia	kg	3.6	
(iii) Low food value : carrot, radish, onion, beetroot	kg	1.6	
Fruit or seed vegetables			
(i) Broad beans, cluster beans, ladyfinger, muskmelon, watermelon	kg	1.9	
(ii) Gourd family vegetables: cucumber family, drumstick giant, green papaya, pumpkin, tomato, chillies	kg	0.8	
Leafy vegetables			
Cabbage, spinach, green mustard leaves	kg	0.8	
Fruits			
(a) Higher food value: tamarind, grapes	kg	11.8	
(b) Low food value: guava, mango, amla, apple, peach, pears, pine apples, ber, sapotta, cashew, citrus	kg	1.9	
Fibre crops (cotton sunnhemp, jute)	kg (dry mass)	11.8	Main product is fibre
Fodder crops (berseem, lucerne, senji, oats, maize, bajra, sorghum, cowpea, guara, napier)	kg (dry mass)	18.0	The main product is dry or green fodder
Green manuring crops (*dhaincha*, cowpea, sunnhemp			Energy equivalent to the amount of nutrients added to the soil through green manuring
Fuel crops: (sunnhemp, *dhaincha*)	kg (dry mass)	18.0	The main product is wood
By Products			
Straw, vines kg (dry mass)	12.5		
Stalks, cobs, fuel wood, fruit vines, plant wood	kg (dry mass)	18.0	
Leaves, vines and straw from vegetables	kg (dry mass)	10.0	
Cotton seed kg (dry mass)	25.0		
Fibre crop seed other than cotton and fuel crop seed	kg (dry mass)	10.0	
Sugarcane leaves and tops	kg (dry mass)	16.1	

Source: Mittal *et al.* (1985)

Animal power: The charges for operating a pair of bullocks are calculated on the basis of the cost of a pair of bullocks, wages of an operator and cost of the feed for bullocks alongwith any other expenses (as enforced in a particular locality) in research farms. However, for the farmers' fields, the actual hiring charges are taken as the basis.

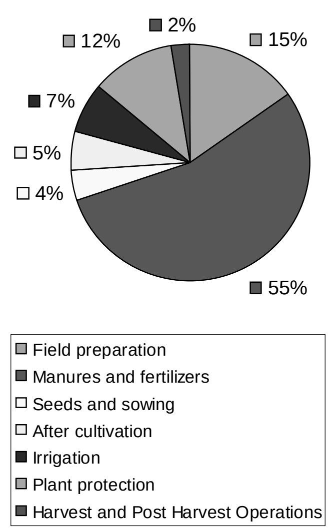
Energy calculation for cotton
(work sheet)

Particulars	Energy Source		
Field preparation			
Tractor ploughing with cultivator - (3 hrs / ha) for 2 ploughings	Mechanical - Tractor	:	$= \frac{\text{Wt. of the tractor (kg)}}{\text{Life span (hrs)}} \times \text{MJ} \times \text{hours of operations}$
			$= \frac{2500}{12000} \times 64.80 \times 6.0 = 80.99$ MJ
	Implement used - cultivator	:	$= \frac{\text{Wt. of the cultivator (kg)}}{\text{Life span (hrs)}} \times \text{MJ} \times \text{hrs of operations}$
			$= \frac{400}{6000} \times 64.80 \times 6.0 = 25.92$ MJ
	Diesel consumption (3.5 litre / hr)	:	For 6 hrs = 6 × 3.5 = 21 litre × 56.31 MJ = 1182.51 MJ
	Driver (Human)	:	= 6 hrs × 1.96 MJ = 11.76 MJ
Pulverizing the soil with rotavator - (3 hrs / ha) for one ploughing	Mechanical - Tractor (3 hrs)		$= \frac{2500}{12000} \times 64.80 \times 3.0 = 40.49$ MJ
	Implement used - Rotavator	:	$= \frac{\text{Wt. of the rotavator (kg)}}{\text{Life span (hrs)}} \times \text{MJ} \times \text{hrs of operations}$
			$= \frac{400}{4000} \times 64.80 \times 3.0 = 19.44$ MJ
	Diesel consumption (3.5 litre / hr)	:	For 3 hours (one ploughing) = 3 × 3.5 × 1.0 = 10.5 litre × 56.31 MJ = 591.3 MJ
	Driver (Human)	:	= 3 hrs × 1.96 MJ = 5.88 MJ
Formation of ridges and furrows by bullock pair	Animal - bullock pair (Medium)	:	= 4 hrs × 10.10 MJ = 40.40 MJ
	Human	:	= 4 hrs X 1.96 MJ = 7.84 MJ
Rectification of ridges & furrows	Human	:	= 10 men X 6 hrs X 1.96 MJ = 117.6 MJ
Manures and fertilizers			
Organic manure application	Farmyard manure (@ 6.25 t ha^{-1}	:	= 6250 × 0.3 MJ = 1875 MJ
	Labour cost for spreading (Human)	:	Men = 2 × 6 hrs × 1.96 MJ = 23.52 MJ (A) Women = 4 × 6 hrs × 1.57 MJ = 37.68 MJ (B) Total = A + B = 63.00 MJ
Inorganic manures	Fertilizer recommendation		
	80 kg N 40 Kg P_2O_5 40 Kg K_2O	:	N = 80 × 60.60 MJ = 4848 MJ P_2O_5 = 40 × 11.1 MJ = 444 MJ K_2O = 40 × 6.7 MJ = 268 MJ
	Labour cost for basal application	:	Men = 1 X 6 hrs X 1.96 MJ = 11.76 MJ (A) Women = 1X 6 hrs X 1.57 MJ = 9.42 MJ (B) Total = A + B = 21.18 MJ
	Cost of micronutrient mixture - (12.5 kg)	:	= 12.5 × 10 MJ = 125 MJ
	Labour cost - basal application		Women = 1× 6 hrs × 1.57 MJ = 9.42 MJ

Seeds and sowing		
	Seeds :	= 15 kg × 25 MJ = 375 MJ
	Biofertilizers :	= 1.2 kg × 10 MJ = 12 MJ
	Sowing (Labour cost) :	Women = 20 × 6 hrs × 1.57 MJ = 188.4 MJ
After cultivation		
	Herbicide :	= 3.3 litre × 120 MJ = 396 MJ
	Application :	Men = 2 × 6 hrs × 1.96 MJ = 23.52MJ (A) Women = 2 × 6 hrs × 1.57 MJ = 18.84 MJ (B) Total = A + B = 42.36 MJ
	Gap filling :	Women = 2 × 6 hrs × 1.57 MJ = 18.84 MJ
	Thinning	Women = 1× 6 hrs × 1.57 MJ = 9.42 MJ
	Hand weeding :	Women = 25 × 6 hrs × 1.57 MJ = 235.5 MJ
	Top dressing :	Women = 1× 6 hrs × 1.57 MJ = 9.42 MJ
	Topping :	Women = 2 × 6 hrs × 1.57 MJ = 18.84 MJ
Irrigation		
	Application :	Men = 20 × 6 hrs. × 1.96 MJ = 235.2 MJ
	Equipment (Diesel motor 5 Hp) :	$= \dfrac{\text{Wt. of the engine (kg)}}{\text{Life span (hrs)}} \times$ MJ × hrs of operations $= \dfrac{150}{10500} \times 64.80 \times 60 = 55.54$ MJ
	Diesel consumption (3.5 litre / spray / ha) :	For 60 hrs = 60 × 3.5 = 210 litre × 56.31 MJ = 11825 MJ
Plant protection		
	Pesticide :	= 2.0 litre × 120 MJ × 4 (spray) = 960 MJ
	Petrol (2.5 lit./ha) :	= 2.5 × 48.23 MJ × 4 = 482.3 MJ
	Human :	Men = 8 × 6 hrs × 1.96 MJ = 94.08 MJ (A) Women = 8 × 6 hrs × 1.57 MJ = 75.36 MJ (B) Total = A + B = 169.44 MJ
Harvest		
	Picking of bolls (Human) :	Women = 30 × 6 hrs × 1.57 MJ = 282.6 MJ
	Drying and sorting (Human) :	Men = 3 × 6 hrs × 1.96 MJ = 35.28 MJ (A) Women = 3 × 6 hrs × 1.57 MJ = 28.26 MJ (B) Total = A + B = 63.54 MJ

Abstracts

Particulars of work	Total energy utilized (MJ)	Total cost (Rs)
Field preparation	2,124	4,633
Manures and fertilizers	7,652	6,123
Seeds and sowing	575	2,736
After cultivation	730	4,487
Irrigation	973	3,400
Plant protection	1,612	3,980
Harvest and Post Harvest Operations	346	3,240
Total	14,012	28,599



Operationwise energy use in cotton

Energy Calculations : Cotton

Particulars	Power source								Total Energy (MJ)	Amount (Rs.)
	Mechanical		Animal		Men		Women			
	Quantity	MJ	Quantity	MJ	Quantity	MJ	Quantity	MJ		
Field preparation										
Tractor ploughing with cultivator - (3 hrs / ha) for 2 ploughings	6 hrs	80.99+25.92			1	11.76			118.67	1500.0
Diesel	21 litre	1182.5							1182.5	735.0
Pulverizing the soil with rotavator -3 hrs @ Rs. 250 / hr	3 hrs	40.49+19.44			1	5.88			65.81	750.0
Diesel	10.5 litre	591.3							591.3	367.5
Formation of ridges & furrows by bullock pair			4 hrs	40.4	1	7.84			48.24	380.0
Rectification of ridges & furrows					10	117.6			117.6	900.0
Total									2,124.13	4,632.5
Manures and fertilizers										
Cost of farmyard manure @ 6.25 t/ha Rs. 400/tonne									1,875	2,782.0
Labour cost for spreading					2	23.52	4	37.68	61.20	540.0
Fertilizer recommendation										
80 kg N									4,848	862.4
40 kg P_2O_5									444	1,125.0
40 kg K_2O									268	231.0
Labour cost for basal application					1	11.76	1	9.42	21.18	180.0
Cost of micronutrient mixture 12.5 kg @ Rs. 25 / kg and application							1	9.42	134.42	402.5
Total									7,651.80	6,122.9
Seeds and sowing										
Cost of seeds 15 kg @ Rs. 60 / kg.									375	900.0
Seed treatment with bio fertilizer									12.0	36.0
Labour cost for sowing							20	188.4	188.4	1,800.0
Total									575.4	2,736.0
After cultivation										
Application of pre-emergence herbicide										
Pendimethalin 3.3 litre @ Rs 405 / litre									396	1336.5
Herbicide application					2	23.52	2	18.84	42.36	360.0
Labour cost for gap filling							2	18.84	18.84	180.0

Energy Calculations : Cotton

Particulars	Power source								Total Energy (MJ)	Amount (Rs.)
	Mechanical		Animal		Men		Women			
	Quantity	MJ	Quantity	MJ	Quantity	MJ	Quantity	MJ		
Labour cost for gap filling							2	18.84	18.84	180.0
Labour cost for thinning							1	9.42	9.42	90.0
Labour cost for hand weeding at 40 days after sowing							25	235.5	235.5	2250.0
Top dressing							1	9.42	9.42	90.0
Nipping of terminal bud on 80 days after sowing							2	18.84	18.84	180.0
Total							730.38	4,486.5		
Irrigation										
Labour cost for 10 irrigation					20	235.2			235.2	1800.0
Electric motor	60 hrs.	22.22							22.22	
Electricity charges									715.8	1600.0
Total									973.22	3,400.0
Plant protection										
Pesticide										
4 sprays @ Rs. 500 / spray									960.00	2000.0
Petrol (4 sprays)	10 lit	482.3							482.3	540.0
Labour cost for spraying					8	94.08	8	75.36	169.44	1440.0
Total									1611.74	3980.0
Harvesting and Post harvest operation										
Picking of bolls – 10 laborers/ picking (3 picking)							30	282.6	282.6	2700.0
Shade drying, sorting and grading					3	35.28	3	28.26	63.54	540.0
Total									346.14	3240.0

kWh, kilowatt-hour – 3.6×10^6 J = 3.6 MJ;
10 hp motor – 1 hour – 1 litre diesel;
hp, horse power – 735.5 w
35 hp motor, 1 hour – 3.5 lit diesel

Source-wise energy (MJ / ha) requirement for Cotton (1 ha area)

Field operation	Direct energy (MJ / ha)							Indirect energy (MJ / ha)							
	Renewable		Total	Non-renewable			Total	Renewable		Total	Non-renewable			Grand Total	G. Total
	Human	Animal		Petrol	Diesel	Electricity		Seed	FYM		Chemical	Fertilizer	Machinery		
Field preparation	143.1	40.4	183.5	-	1,773.8	-	1,773.8	-	-	-	-	-	166.8	166.8	2,124.1
Manures and fertilizer application	91.8	-	91.8	-	-	-	-	-	1,875	1,875	-	5,697	-	5,697.0	7,663.8
Sowing	188.4	-	188.4	-	-	-	-	375	-	375	-	-	-	-	563.4
Irrigation	235.2	-	235.2	-	-	715.8	715.8	-	-	-	-	-	22.2	22.2	973.2
Interculture / weeding	334.4	-	334.4	-	-	-	-	-	-	-	396	-	-	-	730.4
Plant -protection	169.4	-	169.4	482.3	-	-	482.3	-	-	-	960	-	-	-	1,611.7
Harvesting	346.1	-	346.1	-	-	-	-	-	-	-	-	-	-	-	346.1
Total	1,508.4	40.4	1,548.8	482.3	1,773.8	715.8	2,971.9	375	1,875	2,250	1,356	5,697	189.1	7,242.1	14,012.8

Commercial and non-commercial energy used (MJ / ha) for cotton (1 ha area)

Field operation	Commercial energy							Non-commercial energy			Grand Total
	Petrol	Diesel	Electricity	Seed	Fertilizer	Chemical	Machinery	Human	Animal	Farmyard manure	
Field preparation	-	1,773.8	-	-	-	-	166.8	143.1	40.4	1,875	2,124.1
Manures and fertilizer application	-	-	-	-	5697	-	-	91.8	-	-	7,663.8
Sowing	-	-	-	375	-	-	-	188.4	-	-	563.4
Irrigation	-	-	715.8	-	-	-	22.2	235.2	-	-	973.2
Interculture Weeding	-	-	-	-	-	396	-	334.4	-	-	730.4
Plant protection	482.3	-	-	-	-	960	-	169.4	-	-	1,611.7
Harvesting		-	-	-	-		-	346.1	-	-	346.1
Total	482.3	1,773.8	715.8	375	5,697	1,356	189.1	1,508.4	40.4	1,875	14,012.8

Yield of cotton 2300 kg/ha

Energy Productivity	:	Total productivity / Total energy
	:	2300/14012 = 0.164 kg / MJ
Total output energy:		
Total yield	:	2300 kg/ha
I. Main product		
a. 33 % lint × 11.8 MJ	:	759 kg × 11.8 MJ = 8956.2 MJ
b. 67 % seed × 25 MJ	:	1541 kg × 25.0 MJ = 38525.0 MJ
Total (a+b)	:	47481.0 MJ/ha

II. By product:

a. Stalk yield	:	4500 kg × 18.0 MJ = 81000 MJ
Total output energy (I+II)	:	128481 MJ
Total input energy	:	14012 MJ / ha
Output - input energy ratio	:	output energy / input energy

= 9.16 MJ

Energy use and energy productivity of some of the major crops in India

Crops	Crop	Productivity, (kg / ha)	Total energy (MJ / ha)	Energy productivity (kg / MJ)
Cereals	Paddy	3125	13076	0.239
	Wheat	2873	14657	0.196
	Maize	2140	9956	0.215
	Sorghum	950	4745	0.200
Pulses	Green gram	510	4315	0.118
	Black gram	406	3870	0.105
	Bengal gram	596	5464	0.109
Oilseeds	Mustard	960	8051	0.119
	Soybean	1092	6382	0.171
Cash crops	Sugarcane	61500	59192	1.039
	Cotton	938	9972	0.094
	Potato	15520	31352	0.495

Direct Energy	:	4520.7 MJ / ha (32%)
Indirect energy	:	9492.1 MJ / ha (68%)
Total	:	14012.8 MJ / ha
Renewable Energy	:	3798.8 MJ / ha (27%)
Non-renewable energy	:	10214.0 MJ / ha (73%)
Total	:	14012.8 MJ / ha
Commercial Energy	:	10589.0 MJ / ha (76%)
Non-commercial energy	:	3423.8 MJ / ha (24%)
Total	:	14012.8 MJ / ha

Using the above energy sources, we have to work out a model calculation for cotton crop is workedout as follows:

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