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Economic Analysis of Energy Use in Punjab Agriculture

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In the late sixties and early seventies, with the rising trend in utilisation of high-yielding varieties (HYVs) of seeds, intensive irrigation, larger doses of chemical fertilisers, insecticides, pesticides, etc. and the higher level of mechanisation, the corresponding input of energy to Punjab agriculture has increased manifold. About 84 per cent of the cultivated area has been put under crops and the cropping intensity is well over 180 per cent. Along with this, a drastic change has taken place in the cropping pattern. The irrigation and input intensive crops have replaced the traditional crops. Consequently, the direct as well as indirect energy input into Punjab agriculture has shot up. Energy use has largely contributed to the growth of Punjab agriculture directly and indirectly in increasing the productivity level of land and labour. The contribution of land, labour and capital to the growth of agriculture has been well documented in the economic literature. The present study is an endeavour to examine the energy and agricultural growth nexus in Punjab State in historical as well as contemporary perspective. In the first section, the study deals with temporal behaviour of energy consumption pattern and with analysis of energy use. Its contribution to output has been analysed in the second section. In the third section an effort has been made to develop various energy requirement scenarios and the fourth section examines the potential of energy conservation in the agricultural sector of the Punjab State. Section V summarises the findings of the study and the policy implications of the study.

I

ENERGY USE PATTERN

Temporal Behaviour of Energy Use

The temporal behaviour of energy use explains the direction and the extent of energy use in agriculture. Since the time-series data of non-commercial energy inputs were not available, the analysis of temporal behaviour of energy use has been restricted to commercial energy only. Table 1 presents the consumption behaviour of different sources of energy. It can be seen from the table that the consumption of electricity witnessed a sharp increase between 1970-71 and 1994-95. The consumption of diesel increased at a fast pace upto 1980-81 but it started stagnating afterwards while that of nitrogen fertiliser increased consistently throughout the study period. The consumption of phosphorus increased upto 1989-90 but declined in 1994-95 due to the partial withdrawal of subsidies. The total commercial energy input to Punjab agriculture jumped from 32408 X 10^6 to 176236 X 10^6 MJ (mega joules) during the period 1970-71 to 1994-95. The consumption of energy per hectare of net

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TABLE 1. TEMPORAL BEHAVIOUR OF COMMERCIAL ENERGY USE IN PUNJAB AGRICULTURE

Year	Electricity (million kWh)	Diesel (000 litres)	Nitrogen (000 tonnes)	Phosphorus (000 tonnes)	Total energy input (MJ10[6])	Energy input MJ 10[3]/ha	
						Net sown area	Gross cropped area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1970-71	556.20 (6635)	205122 (11550)	225 (13635)	53 (588)	32408	8.00	5.71
1975-76	713.80 (985160)	410145 (23095)	240 (14544)	66 (746)	46904	11.28	7.50
1980-81	1849.80 (22068)	591518 (33308)	526 (31876)	207 (2298)	89550	21.36	13.24
1985-86	2768.10 (33023)	601850 (33890)	787 (47692)	287 (3186)	117791	28.06	16.46
1989-90	5186.60 (61876)	625933 (35246)	818 (49571)	315 (3497)	150190	35.81	20.31
1994-95	6343.00 (75683)	644000 (36264)	1014 (61448)	256 (2841)	176236	41.94	22.98

Source: Singh, 1994; *Statistical Abstract of Punjab, 1996.*
Figures in parentheses denote the inputs in energy terms, i.e., MJ 10^6.

increase in the cropping intensity. To clear this doubt the consumption of energy per unit of gross cropped area was worked out which showed that the energy consumption per unit of gross cropped area also increased from 5.71 thousand MJ in 1970-71 to about 23 thousand MJ in 1994-95. Therefore, it is clear that the energy intensity per unit of area as well as for various crops increased manifold during the period under study. The increase in cropping intensity, shift of area towards energy intensive crops and the introduction of energy intensive HYVs of various crops were mainly responsible for this drastic shift.

Sourcewise Commercial Energy Input

The sourcewise direct as well as indirect energy input[1] into Punjab agriculture has been presented in Table 2. The indirect energy input through fertilisers alone contributed to the tune of 41.72 per cent of the total energy input. The direct energy inputs like electricity and diesel accounted for 32.78 per cent and 25.47 per cent of the total energy input respectively. The indirect use of energy

TABLE 2. SOURCEWISE COMMERCIAL ENERGY CONSUMPTION IN AGRICULTURE

Source (1)	Percentage (2)
Diesel	25.47
Electricity	32.78
Fertilisers	41.72
Chemicals	0.01
Machinery	0.02
Total	100.00

Source: Singh, 1994.

through machinery and chemicals just accounted for a meagre 0.03 per cent. In this way, fertilisers, electricity and diesel emerged as the main sources of commercial energy for agriculture accounting for 99.97 per cent of the total commercial energy input.

Consumption of Energy by Different Size-Groups

The consumption of energy by different size-groups[2] of farmers is of prime importance because almost all the direct and indirect commercial energy sources are under-priced because of subsidies. Therefore, the distribution of subsidies over various sizes of farms can be calculated from this type of analysis. Apart from this, the disproportionality, if any, between the area operated and the proportion of human employment by various categories can also be worked out from this analysis. The farmers having operational holding size more than 4 hectares operated 68.56 per cent of the total operated area of the state and consumed 69.13 per cent of nitrogen, 70.42 per cent of phosphorus, 67.18 per cent of diesel oil and 69.51 per cent electricity. The farmers having operational holdings less than four hectares each consumed 30.86, 29.58, 32.82 and 30.40 per cent of nitrogen, phosphorus, diesel and electricity respectively while their share in the operated area was 31.82 per cent. The categorywise analysis showed that there was little difference between the proportion of area operated and the proportion of use of fertilisers, diesel and electricity by various farm size categories. However, the proportion of the use of animal hours, farmyard manure (FYM) and the human labour was higher than the proportion of the area operated on the lower categories of farms as shown in Table 3.

Cropwise Consumption of Energy Sources

The estimates of cropwise consumption of various energy sources, presented in Table 4, reveal that wheat and paddy crops were the major commercial energy consuming crops of the state. These crops occupying 69.28 per cent of the gross cropped area consumed 92.27 per cent of electricity, 90

TABLE 3. CONSUMPTION OF IMPORTANT ENERGY INPUTS BY DIFFERENT CATEGORIES AT AGGREGGATE LEVEL

Farm size category	Area (000 ha)	Nitrogen (tonnes)	Phosphorus (tonnes)	Diesel (000 litres)	Electricity (000 kWh)	Animal pair (000 hrs)	FYM (000 qtl)	Human labour (million hrs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I	139 (3.38)	29,736 (3.32)	9,901 (3.12)	20,886 (3.34)	1,16,464 (3.06)	6,700 (3.96)	8,803 (4.80)	205 (4.49)
II	311 (7.58)	64,169 (7.17)	23,459 (7.39)	52,120 (8.34)	2,41,010 (6.34)	20,400 (12.04)	14,334 (7.81)	390 (8.54)
III	840 (20.46)	1,82,254 (20.37)	60,530 (19.07)	1,32,300 (21.14)	8,01,360 (21.09)	49,000 (28.94)	37,850 (20.62)	998 (21.84)
IV	1,589 (38.72)	3,51,370 (40.41)	1,19,572 (37.67)	2,38,715 (38.13)	15,75,144 (41.43)	56,700 (33.49)	73,110 (39.83)	1,738 (38.05)
V	1,225 (29.86)	2,56,821 (28.72)	1,03,917 (32.75)	1,81,912 (29.05)	10,67,624 (28.08)	36,500 (21.57)	49,466 (26.94)	1,237 (27.08)
Overall	4,104 (100.00)	8,94,350 (100.00)	3,17,379 (100.00)	6,25,933 (100.00)	38,01,602 (100.00)	1,69,300 (100.00)	1,83,563 (100.00)	4,568 (100.00)

Source : Singh, 1994.
Figures in parentheses denote percentages.

per cent of diesel oil, 80.89 per cent of phosphorus and 80.94 per cent of nitrogen. Paddy crop alone consumed about 76 per cent of the electricity while wheat crop consumed about 60 per cent of diesel oil. These two crops taken together account for only 53.19 per cent of human labour use, 46.02 per cent of animal use and 51.76 per cent of FYM use. The American cotton plus all other crops depended more on the use of human and animal energy. So from the point of view of the conservation of energy, wheat and paddy emerged as the important crops and the conservation efforts need to be focused upon these crops.

II

ENERGY USE AND OUTPUT GROWTH RELATIONSHIP

It is widely accepted that the growth in productivity of resources is essential for the development of the economy. In the economic literature emphasis was laid on the development of land and labour saving technologies to produce maximum output per unit of land and labour because of their relative scarcities. However, as the development proceeds both human and physical capital inputs play increasingly an important role. Kuznets (1971) discussed that higher productivity per worker in

TABLE 4. CROPWISE CONSUMPTION OF INPUTS

Source/Crop (1)	Wheat (2)	Paddy (3)	American cotton (4)	Others (5)	Total (6)
Human labour (million hours)	1160 (25.39)	1270 (27.80)	575 (12.59)	1563 (34.22)	4568 (100.00)
Animal labour (000 hrs)	49992 (29.53)	27914 (16.49)	36831 (21.75)	54563 (32.23)	169300 (100.00)
FYM (000 qtls)	22298 (12.15)	72707 (39.61)	6833 (3.72)	81725 (44.52)	183563 (100.00)
Nitrogen (tonnes)	429330 (48.01)	294552 (32.93)	59245 (6.62)	111223 (12.44)	894350 (100.00)
Phosphorus (tonnes)	208316 (65.64)	48397 (15.25)	2425 (0.76)	58241 (18.35)	317379 (100.00)
Diesel (000 litres)	374942 (59.90)	188504 (30.12)	37897 (6.05)	24589 (3.93)	625932 (100.00)
Electricity (000 kWh)	621634 (16.34)	2886402 (75.93)	31439 (0.83)	262127 (6.90)	3801602 (100.00)
Area under crop (000 ha)	3216 (43.51)	1905 (25.77)	733 (9.92)	1537 (20.80)	7391 (100.00)

Source: Singh, 1994.
Figures in parentheses denote percentages.

the industrial sector could be the result of either a greater supply of material capital per worker or higher return per unit of capital or both. The same is true in the developing phase of agriculture. The adoption of new technology requires relatively less labour and the share of capital inputs, which require energy for their manufacturing and operation increases over time. Enhanced energy input augments the land and labour productivity in agriculture. But how the output per unit of energy itself behaves over time also needs to be examined.

The relationship between the gross value of product and energy consumption has been given in Table 5. It may be noted that the gross value of the output in real terms, i.e., at 1970-71 prices, increased from Rs. 656 crores in 1970-71 to Rs. 1,624 crores in 1994-95. The gross value of the output per thousand MJ of energy declined from Rs. 202 in 1970-71 to Rs. 97 in 1980-81 and further to Rs. 92 in 1994-95. The gross value of output per thousand MJ of energy fell sharply upto 1980-81 and thereafter remained almost stagnant with little fluctuations. The use of energy intensive technique of production and the structural change (cropping pattern) in agriculture in the early phase were mainly responsible for this decline. However, it is feared that with the decline in ground-

TABLE 5. RELATIONSHIP BETWEEN COMMERCIAL ENERGY INPUT AND GROSS VALUE OF PRODUCT

Year (1)	Energy input (MJ 10^9) (2)	Gross value of output in real terms at 1970-71 prices (Rs. crores) (3)	Gross value of output per 000 MJ of energy (Rs.) (4)
1970-71	32.408	656	202.4
1975-76	46.901	732	156.1
1980-81	89.550	871	97.3
1985-86	117.991	1259	106.7
1989-90	150.176	1467	97.6
1994-95	176.236	1624	92.2

Sources: Economic and Statistical Organisation, Punjab, Government of Punjab, Chandigarh; Singh, 1994.

water table, increasing nutrient deficiencies and lack of breakthrough in the energy saving technique of production, the direct and indirect energy requirement for sustaining the yield levels achieved will further increase and the returns per unit of energy are likely to decline in future. Therefore, the energy conservation efforts are needed to be stepped up because the energy scarce country like India cannot consistently augment the energy supply to agriculture keeping in view the high opportunity cost of energy.

In order to determine the relative contribution of different inputs to gross value of output, the data were subjected to production function analysis. For this purpose the gross value of output in rupees was considered as a function of farm size in hectares, expenditure on fertilisers in rupees, expenditure on chemicals other than fertilisers in rupees, tractor hours, human labour hours and irrigation hours. It would have been better to convert these inputs into energy units for production function analysis but the limitation of conversion and aggregation (Singh, 1993) prohibited the conversion into energy units. Table 6 shows the regression coefficients and the related statistics of Cobb-Douglas equations on different sizes of farms and the state as a whole. It would be seen from the table that the gross value of output was significantly affected by net sown area, expenditure on fertilisers and use of tractors in the first category of farms. In the second category of farms, the net sown area, expenditure on fertilisers and expenditure on chemicals significantly affected the gross value of output. So increasing the gross value of output is possible on these farms by increased use of fertilisers and chemicals. The expenditure on fertiliser also affected the gross value of output in the third category of farms at 10 per cent level of significance. Similarly, the expenditure on fertiliser and use of tractor in hours affected the gross value of output significantly in the fourth category of farms. For the state as a whole, the net sown area, expenditure on fertiliser and chemicals contributed significantly to the gross value of output. Therefore, it implies that the use of energy can be increased only through those inputs which significantly contribute to the gross value of output.

TABLE 6. REGRESSION COEFFICIENT AND RELATED STATISTICS OF COBB-DOUGLAS EQUATIONS ON DIFFERENT SIZES OF FARMS AND PUNJAB STATE

Variables	Farm size category					Punjab
	I	II	III	IV	V	state
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Net sown area	0.3524*	0.3065**	0.0376	0.6848	0.7819**	0.3483*
(ha)	(0.1276)	(0.1202)	(0.2932)	(0.4203)	(0.3334)	(0.1028)
Fertiliser (Rs.)	0.4182*	0.4857*	0.4862***	-0.5458	0.4662	0.3382*
	(0.1001)	(0.0971)	(0.2560)	(0.3632)	(0.2884)	(0.1005)
Chemicals (Rs.)	0.0141**	0.0233*	0.0161	0.2896**	0.0236	0.0204*
	(0.0057)	(0.0086)	(0.1346)	(0.1337)	(0.0305)	(0.0064)
Tractor (hours)	0.2020**	0.0313	0.1030	0.3285*	-0.1712	0.9700***
	(0.0877)	(0.0711)	(0.1315)	(0.1269)	(0.1686)	(0.0540)
Human (hours)	0.0407	0.1709	0.2403	0.3831	-0.2286	0.1863***
	(0.4301)	(0.1137)	(0.3015)	(0.3592)	(0.2610)	(0.1027)
Irrigation (hours)	-0.0027	-0.0021	-0.0061	0.0040	0.0198	0.0004
	(0.0044)	(0.0046)	(0.0108)	(0.0125)	(0.0132)	(0.0041)
Intercept	5.7714*	4.812*	4.3269*	8.2224**	8.4689*	5.6042*
	(0.8215)	(0.7666)	(0.2392)	(3.2327)	(2.5115)	(0.7907)
R^2	0.82	0.89	0.48	0.51	0.42	0.80

Source: Singh, 1994.

*, ** and *** Significant at 1, 5 and 10 per cent respectively.

Figures in parentheses indicate standard errors.

III

ENERGY REQUIREMENT SCENARIOS

The development of energy requirement scenarios in the agricultural sector depends upon how accurately the future character of agriculture and food system is predicted. It is a complex task to exactly predict the character of agriculture. However, some of the relationships that determine the character can be identified. First, it depends upon the pattern and pace of technological change which may take place in the near future. But the technological change requires substantial time to develop, test and disseminate. The capital stock associated with a particular technology will only be replaced or discarded if the economic benefit from the alternative technology is enough to outweigh the cost of capital discarded or replaced. The government policy encouraging the adoption of new technology and replacing the old one is also of paramount importance. The macro effects of new technology such as the effect on employment, imports and exports, credit policies also need to be considered even though the benefit-cost ratio may be favourable at the micro level. The second important factor is how the demand for agricultural commodities will behave. If the structure of demand changes, then the demand for energy may increase or decrease. If the demand for those commodities, whose production requires large amounts of energy, increases, then the requirement of energy will increase otherwise it will behave the other way. Thirdly, the changes in relative prices of energy resources can cause substantial changes in the use of various energy sources. However, the farmer will think of substitution of costly energy sources with the cheap ones only if the proportion of energy cost in the total cost is substantial or the increased cost is not compensated with the increase in prices of output or subsidies. On the other hand, the shortage of energy in form, time and place may induce energy substitution, conservation or switching to new technology. Fourthly, the demand for energy may be managed through alternative new practices and the use of renewable sources. But the risk and uncertainty associated with new and unproven practices may inhibit their use in the near future. Lastly, the governmental polices of subsidies, price support, research and development can change the structure of agriculture and correspondingly the energy demand. The economic and political compulsions and regional considerations play a great role in determining the government policies of agriculture development.

In Punjab agriculture, as perceived on the theoretical basis given above, any large changes in the agricultural structure are unlikely to occur in the near future. The Punjab agriculture is likely to remain largely a crop based one. Within the crop system the technological breakthrough in the crops, other than wheat and paddy, may take place but the government policies will continue to retain Punjab as a major foodgrains producing state. A study conducted recently (Acharya, 1993) shows that in the major wheat producing states like Punjab, Haryana and Uttar Pradesh where the yield of wheat is quite high, the area under wheat has increased because other crops have failed to compete with wheat. The study further recognised that the high prices of oilseeds could lead to shift of acreage in favour of oilseeds from cereals and due care was taken to check this shift through price policy measures. Apart from relative economics, the price and yield fluctuations and climatic factors prohibit the shift from paddy to cotton or other crops. Similarly, the capital stock with the farmers have developed in such a way that the comprehensive shift from present production pattern is impossible unless accompanied by large economic advantage. The stock in the form of irrigation structure, storage, tractors, etc., and the associated simplified work induce the farmers to maintain the *status quo*. Even at the macro level, the production and marketing infrastructure required cannot be built up in a short span of time.

The demand induced structural change in Punjab agriculture is again impossible because this state has a large national market for foodgrains and a supporting transportation system to move foodgrains from this state to rest of India. In this way, firstly, in the present circumstances the demand for commodities other than foodgrains is unlikely to increase and secondly, if demand increases then it will take a lot of time to develop the efficient transportation system to transport the commodities like fruits, vegetables, eggs and milk to other states. Therefore, there is little scope for large scale shifts in the demand for energy resources due to the structural shifts in the agriculture of Punjab in the near future. The changes in the relative prices of various energy resources could cause a change in the demand for various energy sources but empirical evidence for the last twenty years points out that the scope for such a change in the demand for various energy sources has already been exhausted. Lastly, the replacement of non-renewable with alternative renewable energy resources is uneconomical at the present level of technology and is prone to risk and uncertainty. Apart from this, a number of other constraints do limit their use in the near future (Singh, 1994).

So from the foregoing discussion it is clear that the energy scenario in Punjab agriculture is likely to witness little change. However, the behavioural and attitudinal changes on the part of the farmers can result in limited alteration in the structure of agriculture. There are three options of the attitudinal and behavioural changes of the farmers. First, the farmers can maximise profit by developing optimum production plans with readjustments in the existing land and other resources. Second, the farmers led by the demonstration effect can adopt the technology used by the progressive farmers. Third, the farmers can use the technology recommended by the agricultural research institutions.

Keeping in view the behavioural path of the farmers noted above, the energy requirements from various sources have been worked out. Fortunately, a study on optimisation of agricultural production with farming system research perspective in Punjab (Singh, 1992) was conducted by applying the profit maximisation model of linear programming, and optimum cropping pattern with the readjustment of the available resources was worked out in this study. Consequent upon the shifts in the cropping pattern, the requirement of various energy resources were worked out at existing level of technology (ELT), progressive farmers' level of technology (PFT) and recommended level of technology (RLT). Here ELT refers to the technology at which farmers are currently operating and PFT refers to the level of technology as practised in the field by the upper 20 per cent of the high productivity farms. RLT means the technology recommended by the Punjab Agricultural University for different crops. Present level (PL) of use means the consumption of energy inputs at present level without any shift in the cropping pattern.

Table 7 presents the employment of various resources at present and in normative plans at various levels of technology. The average use of tractor in the first category of farms increased from 21.58 hours per hectare at present level to 35.91 hours when the farmers readjusted the existing resources to maximise profits. The use of tractor further increased to 47.47 hours if the use was to be matched with the use level of the top 20 per cent of the farmers called the progressive farmers. It further increased at recommended level of technology because of the elimination of bullock use. In this way, the use of tractor increased when there was shift from PL to ELT, PFT and RLT. However, the rate of increase in the tractor use declined with the size of the farm because the large size farms were already using the tractor for more hours than the marginal and small farms. In the first category of farms, the use of tractor witnessed a three-fold increase with a shift from PL to RLT. But in the fifth category of farms the increase was from 31.71 hours to 37.51 hours per hectare. Therefore, it is envisaged that slowly the marginal and small farmers will try to adopt this path and the use of tractors will increase on these farms.

The use of diesel engines also increased with the adoption of ELT, PFT and RLT. The diesel engines are meant for assured irrigation and the shifting of cropping pattern in favour of irrigation intensive crops is responsible for this. The per hectare usage of diesel engines was 78.25, 101.72, 131.46 and 154.94 hours at PL, ELT, PFT and RLT respectively in the first category of farms. Its use was 16.36, 19.63, 19.46 and 21.76 hours at PL, ELT, PFT and RLT respectively in the fifth category

TABLE 7. PER HECTARE AVERAGE EMPLOYMENT OF VARIOUS SOURCES AT PRESENT AND IN NORMATIVE PLANS AT VARIOUS LEVELS OF TECHNOLOGY

Source	Technology	Farm size category				
		I	II	III	IV	V
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tractor use (hours)	PL	21.58	18.04	23.42	29.15	31.79
	ELT	35.91	28.56	32.79	34.40	36.88
	PFT	47.47	41.88	36.06	41.98	37.19
	RLT	64.09	47.60	37.70	44.89	37.51
Diesel engine (hours)	PL	78.25	81.99	49.37	26.19	16.36
	ELT	101.72	106.58	64.18	32.48	19.63
	PFT	131.46	131.18	71.09	34.57	19.46
	RLT	154.94	152.50	101.70	53.95	21.76
Electric motor (hours)	PL	219.47	193.74	238.50	247.82	217.89
	ELT	225.02	199.55	250.43	262.69	265.82
	PFT	255.61	226.67	255.20	266.24	255.93
	RLT	251.74	221.24	208.59	202.43	214.54
Nitrogen use (kg)	PL	213.93	206.33	216.97	227.42	229.65
	ELT	280.25	268.22	238.67	250.61	278.88
	PFT	293.00	293.00	262.53	270.63	261.80
	RLT	226.76	218.71	227.60	234.72	235.40
Phosphorus use (kg)	PL	71.23	75.43	72.06	75.25	84.83
	ELT	91.31	98.81	79.26	82.78	101.80
	PFT	109.17	86.74	82.15	87.27	109.91
	RLT	84.05	89.00	82.06	87.29	98.40
Human labour (hours)	PL	1,475	1,256	1,118	1,094	1,010
	ELT	1,873	1,570	1,397	1,367	1,232
	PFT	1,666	1,444	1,263	1,214	1,050
	RLT	1,917	1,582	1,375	1,345	1,242

Source: Singh, 1994.

of the farms. Similarly, the per hectare use of electric motors and fertilisers increased with a shift in the technological level. However, the use of electric motors and fertilisers declined at the recommended level of technology due to the elimination of over-use. This points out that the use of electric motor and fertilisers increased at ELT and also at PFT level but declined at RLT because the farmers usually apply higher doses than those recommended by the experts. The use of human labour also accompanied the technological shifts but the use of human labour increased more sharply in the smaller size of farms than on the large farms.

The consumption of various energy sources at different levels of technology for the Punjab State as a whole was also worked out and the data are presented in Table 8. The per hectare consumption on various size categories of farms has been weighted with the area operated by these farms. The consumption of diesel increased from 625.9 million litres at PL to 785.2 million litres at ELT, to 891.4 million litres at PFT level and further to 1013.4 million litres at RLT. The consumption of electricity and fertilisers increased upto PFT level and declined at RLT. The use of human labour increased at ELT and RLT but declined at PFT level.

To conclude the consumption of total commercial energy input increased from 138319 X 10^6

TABLE 8. CONSUMPTION OF VARIOUS INDIRECT AND DIRECT ENERGY SOURCES AT AGGREGATE LEVEL FOR THE PUNJAB STATE

Source	Technology	Farm size categories					Total
		I	II	III	IV	V	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Diesel (000 litres)	PL	20896	52120	132300	238715	181912	625933
	ELT	30028	71928	179827	284383	219057	785220
	PFT	39236	96105	198274	337408	220402	891425
	RLT	49526	!10389	234889	393182	225437	1013423
Electricity (million kWh)	PL	117	241	801	1575	1069	3802
	ELT	125	248	841	1670	1303	4187
	PFT	142	282	857	1692	1254	4227
	RLT	140	275	701	1287	992	3395
Nitrogen (00 tonnes)	PL	297	642	1823	3514	2565	8944
	ELT	390	834	2005	3982	3416	10627
	PFT	407	911	2205	4300	3207	11030
	RLT	315	680	1912	3730	2884	9521
Phosphorus (00 tonnes)	PL	99	235	605	1196	1039	3174
	ELT	130	307	666	1316	1247	3665
	PFT	152	270	690	1387	1346	3845
	RLT	117	277	689	1387	1205	3675
Human labour (million hours)	PL	205	390	998	1738	1237	4569
	ELT	260	488	1176	2172	1509	5602
	PFT	232	449	1061	1929	128	4957
	RLT	266	492	1155	2137	1521	5571

Source: Singh, 1994.

TABLE 9. TOTAL COMMERCIAL ENERGY INPUT FROM MAIN SOURCES AT VARIOUS LEVELS OF TECHNOLOGY

$(MJ\ 10^{6})$

Source	Level of technology			
	PL	ELT	PFT	RLT
(1)	(2)	(3)	(4)	(5)
Diesel	35246	44216	50196	57066
	(28.48)			
	(27.19)	(29.23)	(39.80)	
Electricity	45353	49951	50428	45502
	(32.79)	(30.71)	(29.36)	(31.74)
Fertilizer	57720	68468	711110	40793
	(41.73)	(42.10)	(41.41)	(28.46)
Total	138319	162635	171734	143361
	(100.00)	(100.00)	(100.00)	(100.00)

Source: Singh, 1994.

MJ at PL to 162635 X 10^6 MJ at ELT level, to 171734 X 10^6 MJ at PFT level and 143361 X 10^6 at RLT as shown in Table 9. In this way the total commercial energy input increased by 18 per cent while moving from PL to ELT, by 24 per cent from PL to PFT and by only 4 per cent from PL to RLT. The proportion of various resources did not witness much change except at RLT where the share of diesel increased sharply and the share of fertilisers declined.

IV

ENERGY CONSERVATION POTENTIAL AND PROBLEMS

The agricultural sector of the low income countries like India is considered as less energy intensive sector and a hopeless area of energy conservation (Leach, 1986; Stout, 1990), ignoring the fact that even in these countries there are regions where agriculture has become energy intensive. A lot of inefficiencies exist in the utilisation of energy sources which can be rectified with little effort. Pathak (1985) found that the overall system efficiency of irrigation with diesel engines was only 2.7 per cent in comparison to the 12.3 per cent attainable limits. Another study on electric driven tubewells conducted by Punjab Agricultural University showed that only 33 per cent of the tubewells were having 50 per cent level of efficiency, 21 per cent of the tubewells were having 45 to 50 per cent level of efficiency, 15 per cent of the tubewells were having 40 to 45 per cent level of efficiency and 31 per cent of the tubewells were operated at efficiency levels less than 40 per cent. The price policy for energy sources, lack of proper maintenance, groundwater table fluctuations and the tendency of the farmers to over-irrigate were listed as the main reasons for this sorry state of the affairs.

The flat rate electricity pricing system was in operation till March 1997 and thereafter the electricity supply was made free of cost. The free supply or the flat rate pricing system provides no incentive for energy saving because of zero marginal cost of irrigation. The farmers tend to own low efficiency irrigation equipment and the number of irrigations applied is more than the recommended level. Singh (1994) analysed the cost of cultivation data and found that about 55 per cent of the farmers applied near to the adequate number of irrigations, i.e., 25 to 32 irrigations to the paddy crop. About 19 per cent of the farmers applied 33 to 40 irrigations, 15 per cent of them applied 40 to 50 irrigations and the remaining 11 per cent applied more than 50 irrigations. The highly subsidised flat rate price system also induced the farmers to put the marginal lands under the irrigation intensive crops like paddy and apply higher number of irrigations. The remedy lies in linking the electricity charges with the extent of use even though the charges may be subsidised. Singh (1994) also found that only through the system improvement of the electric driven tubewells, 2124 million kWh of electricity can be saved which amounts to more than 30 per cent of the total electricity consumed in the agricultural sector. The mandatory standardisation of diesel engine can result in 12 to 15 per cent saving of the total quantity of diesel consumed through the use of diesel engines.

Fertilisers accounted for about 42 per cent of the total commercial energy input for the Punjab agriculture. But at present the fertiliser use efficiency is as low as 30 per cent. Mudahar and Hignett (1982) found that the fertiliser use efficiency can be increased upto 80 per cent through appropriate fertiliser use management systems which include appropriate nutrient dose based on soil survey, right time and method of application and consistently maintaining the proper nutrient balance of the soils. Though it is not possible to increase the efficiency level upto 80 per cent yet just a moderate increase in the efficiency from 30 to 40 per cent can result in the saving of 224 thousand tonnes of nitrogen and in turn 13549 X 10^6 MJ of energy.

Another area of energy conservation is the change in the cropping pattern in favour of less energy intensive crops. For example, replacing one hectare of wheat and paddy with annual sugarcane crop, there could be a saving of 19789 MJ of energy (Singh, 1994). The requirement of electricity and fertilisers will decline but the requirement of diesel will increase. Similarly, there are many other alternatives but certain macro and micro level constraints put a brake upon such changes. At the present level of costs and returns, only sugarcane crop is superior to wheat and paddy crop rotation both in terms of annual returns to fixed farm resources (Chahal and Chahal, 1989; Johl, 1986) and energy saving. But the marketing constraints limit the change in cropping pattern in favour of sugarcane.

The recycling of residues and energy generation from the residues provide a fair scope for energy conservation. The direct recycling of available residues and cattle dung can result in the saving of 182 thousands tonnes of nutrients (Singh, 1994). Apart from this, 506 million cubic-feet of biogas can be produced from dung. The rice straw and cotton stalks are good source of producer gas to run the gasifiers but this technology needs improvements.[3] Presently, more than 50 per cent of these residues are used injudiciously.

V
CONCLUDING OBSERVATIONS

The findings of the present analysis can be summarised as follows: the total energy use as well as energy use on per hectare basis increased considerably as the agricultural development proceeded in the state. The increase in the electricity use was much sharper than the other sources. The indirect energy consumption through fertilisers and the direct energy from electricity and diesel accounted for 99.97 per cent of the total commercial energy input to agriculture. The categorywise analysis revealed that the farmers having operational holdings more than four hectares each accounted for a major chunk of energy consumption as well as the subsidies provided on them. Rice and wheat emerged as the major energy consuming crops of the state. The value of output per unit of energy input declined at a very sharp rate during the development phase (upto 1980-81) and it started stagnating in the stagnation phase of agriculture, i.e., from 1980-81 onwards. The production function analysis showed that expenditure on fertilisers and chemicals still significantly contributes to the production on small farms. The impact of technological path, likely to be adopted by the farmers, showed that there will be 18 per cent increase in energy consumption if the farmers readjust the resources and maximise the profits. Energy consumption will increase by 24 per cent if the farmers moved to progressive farmers' level technology and by only 4 per cent if the farmers adopted the recommended level of technology. The adoption of recommended level of technology presumes the maximum attainable efficient use of various resources and elimination of over-use. The increase in the efficiency of use of various energy sources emerged as the major option of energy conservation in agriculture.

It can be concluded from the foregoing analysis that energy has played a major role in the agriculture development of the state. The energy policy especially the policy on the mode of providing subsidies requires a fresh look. Since agricultural development has reached a plateau in the state with almost no scope of change in net sown area, cropping intensity, irrigated area, cropping pattern, etc., in the near future, the requirement of energy will be determined by the behaviour of the farmers reflected in the technological path adopted by them. The potential of energy conservation needs to be realised through mass education campaign and by providing economic incentive to conservation and imposing disincentives on inefficient use. Sustained efforts are needed to look for an economically suitable alternative to paddy crop which is largely responsible for power and groundwater consumption. A shift of 20 per cent of the area from paddy will considerably reduce the pressure on electricity demand because paddy crop alone accounts for three-fourths of the total electricity consumed in the agricultural sector.

NOTES

1. The electricity, diesel, human and animal labour have been classified as direct sources while fertilisers, chemicals, machinery, etc., have been classified as indirect sources of energy. The Indian Council of Agricultural Research has developed the conversion factors (Mittal and Dhawan, 1986) to convert various energy inputs into common energy unit, i.e., mega joules.

2. In a study conducted by Singh (1994) the farmers were classified into five standardised categories of farms based on the operational holdings. The categories were: (i) upto one hectare, (ii) 1 to 2 hectares, (iii) 2 to 4 hectares, (iv) 4 to 6 hectares and (v) 6 hectares and above.

3. Gasifiers produce the producer gas which can be used to run the dual fuel engines. There is a saving of about 60 per cent diesel in dual fuel engines.

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