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POLICY PAPER 41

Sustainable Energy for Rural India

NAAS

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

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SUSTAINABLE ENERGY FOR RURAL INDIA

PREAMBLE

Agriculture in a way is an energy conversion industry. Through photosynthesis, plants transform solar and chemical energies derived from the soil into storable chemical energies as carbohydrates, proteins, fats, cellulose, dietary minerals, vitamins and phytomins, etc. To increase photosynthetic efficiency of plants, the plant breeders evolve better plant types, while other scientists develop efficient agro-techniques, hardwares and softwares of management. Current package of practices of crop production involve various sources of energy - some are locally available non-commercial while others are commercial such as, diesel and electricity, certified seeds and planting materials, fertilizers, pesticides, farm machinery, post-harvest equipment and structures, cold stores as well as refrigerated carriers for perishables. Excessive use of commercial energies in Indian scenario, where 70% petroleum products are imported and where electrical power is costly and in short supply, means increased unit cost of production of agricultural products, and reduced profitability and global competitiveness.

In a village eco-system, about 80% of the total energy use goes to domestic sector of which about 80% is used for cooking, mostly derived from crop and livestock residues and fuel wood. Rural electrification and socio-economic developments have provided electricity, kerosene, and biogas for resourceful rural homes. However, supply of electricity to the rural areas is not adequate; and it is not available when required most. Farmers have to wait for a long time for energisation of their irrigation pumps. Rural entrepreneurs are constrained to have stand-by power supply unit run on diesel or biomass which supply electricity at 2-3 times the cost of that obtained from grid power. Government of India has established Ministry of New and Renewable Energy, and State Governments have created corporate bodies promoting new and renewable energy sources. As a result of intensive R&D in public and private sector, a number of renewable energy applications like improved *chulhas*, biogas plants, solar cookers, solar water heaters, solar dryers, photovoltaic irrigation pumps and illumination systems are under massive popularization. Wind farms are generating substantial quantities of electricity for power grid and off-grid applications. Energy from biomass is also being generated on a pilot scale. Energy plantations are being taken up in a big way on reclaimed lands for biodiesel production. Blending of petrol with ethanol has started. Energy needs to be conserved, and commercial energies need to be supplemented and substituted with renewable energies to sustain rural economy and living.

With this background, the National Academy of Agricultural Sciences (NAAS) in collaboration with SKUAST-K organized a brainstorming session on “Energy for Rural India-Issue and Options” under the convenership of Prof. Anwar Alam at Shilimar Campus, Srinagar, J & K on October 25, 2007. The detailed recommendations emerging from the deliberations have been brought out in this policy paper.

ENERGY IN AGRICULTURE

Farm Power for Production Agriculture

Unlike industry where men and materials are brought under one roof to produce manufactured goods, agriculture demands movement of men and materials to and from every field. Thus, for field operations tractive power becomes a basic requirement. Farm power is also required to provide shaft power to do stationary jobs like lifting irrigation water, running a power thresher, etc., for which electric motors and diesel engines are used, former being a more efficient and cheaper option if available from power grid. To take advantage of advances made in the developed countries in agriculture to tide over acute foodgrain shortages, India experimented and adopted some of the relevant technologies like high yielding crop varieties that responded to fertilizer and other inputs. Mechanization of agriculture was also one such adoption and indigenous manufacture of pumping sets, tractors and power tillers along with their attachments such as mouldboard and disc ploughs, disc and tine type harrows, seed drills, and seed-cum-fertilizer drills started in 1960's. Indigenous R&D led to development of equipment for threshing and winnowing, reaping, transplanting, interculture, combining, earthwork, levelling and grading, conservation tillage, etc. in the following years.

Agricultural mechanization in the developed world was directed to create surplus labour for deployment in industrial sector which created such a demand. In India, it is primarily directed to have economical and efficient power source that enables the worker to speed up the job of desired quality and to achieve timeliness in field operations. Mechanization also helps in precisely metering, and placing the seed and fertilizer at proper depth. It also removes drudgery and imparts dignity to farm work, which is otherwise looked down upon socially. Animate sources per unit energy are costlier than electro-mechanical, since the animals need to be fed and maintained when not in use and they have work-rest period. It also involves excessive walking by man or animal. For example, to plough one hectare of land one has to walk about 40 km. Wheat seedbed may require 3-4 passes. The number and the annual use of draft animals has declined.

There has been steady growth in use of electro-mechanical power sources in the country since 1960s, and more significantly after the Green Revolution (**Table 1**). On an average, there has been a 9.84% per annum growth during 1960-1997. By the year 2000, tractor population increased to about 2.5 million from a mere 31000 in 1960. Power tiller manufacture also started about the same time but has not become as popular as tractors; their estimated population is about 125000 while the annual production around 15000.

Energy in Production Agriculture

Traditional agriculture is mostly dependent on non-commercial energy sources, whereas the modern agriculture largely depends upon commercial energy sources (fuel, machinery

Table 1. Population growth trends in mechanical farm power sources in India

	1950	1960	1970	1980	1990	1997	2000	Growth rate (%) Base year 1970
Tractive power (number in million)								
Tractor	0.008	0.031	0.148	0.518	1.222	2.037	2.471	9.84
Power Tiller	-	-	0.003	0.021	0.040	0.085	0.110	12.7
Stationary power (number in million)								
Electric pump	0.020	0.100	1.629	4.330	6.01	8.254	9.525	6.06
Diesel pump	0.083	0.230	1.546	3.101	4.659	5.899	6.465	4.88
Others (number in million)								
Power sprayer/duster	-	-	0.045	0.124	0.200	0.245	0.311	6.66

and chemicals). As an example, highly mechanized food system of U.S.A uses about 16.5 per cent of the total national energy (crop production 18%, food processing 33%, transportation 3%, wholesale/retail distribution 16%, for cooking 30%), about 80 per cent of which is provided by petroleum products.

Energy and Agricultural Production Nexus

Table 2 clearly indicates a nexus between energy (farm power availability) and agricultural productivity. The total energy use in production of principal crops in India has increased 4.5 times between 1970 and 2005 for the increase in productivity from 837 to 1583 kg/ha (**Fig.1**). The contribution of animal energy has significantly decreased from 43.9% to 5.8% and human energy from 36.7% to 7.9%. Commercial energy has increased significantly during the period (electricity from 0.19 to 38.1%, diesel from 2.4% to 18.3% and fertilizer from 16.4% to 29.7%). This exhibits the increasing dependence of Indian agriculture on commercial energy.

Steady increase in labour wages and advent of farm labour unions has compelled farmers to go for mechanization. Socio-economic factors of drudgery to farm workers, declining interest of educated rural youth towards farming, and low order of dignity to farm work have also contributed towards increasing trend in mechanization. By mid eighties, electro-mechanical energy use in Indian agriculture reached to over 80% of the total operational energy. There is close nexus between degree of agricultural mechanization energy use and agricultural production and productivity (**Fig. 2**). However, there are also incidences where over mechanization has resulted in indebtness of the farmers as in Punjab. Small and

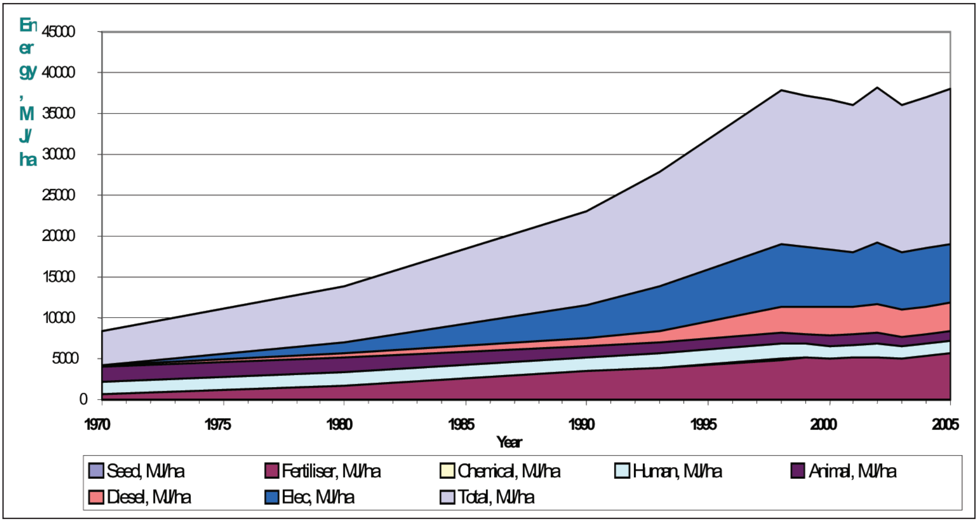


Fig.1. Source-wise energy consumption in India agriculture

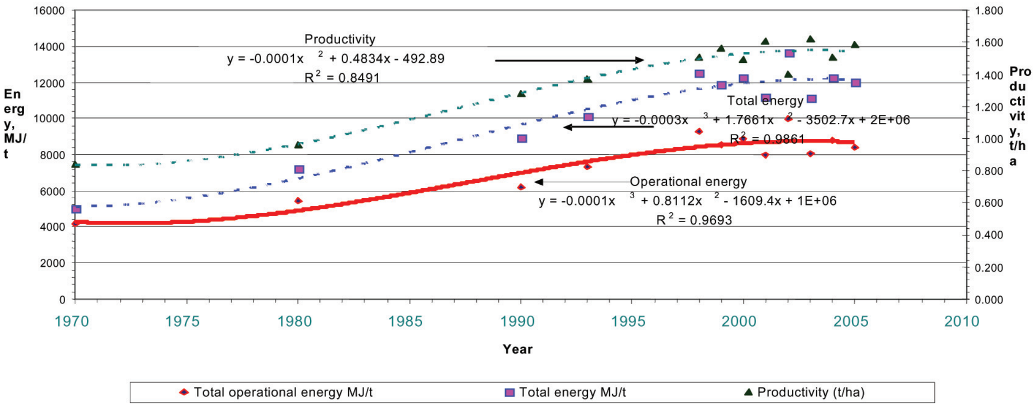


Fig. 2. Trend of operational energy consumption in Indian agriculture

marginal farmers can meet their requirements of costly machines through custom servicing which should be developed.

Agriculture in Punjab after the Green Revolution has been most input intensive with abundant use of inputs like irrigation, fertilizers, farm power and necessary agro-chemicals for plant protection, and the energy use has consequently been one of the highest in the country (**Table 2**). It may be noticed that paddy cultivation in light soils and under high ambient temperature requires exceptionally high-energy use due to very frequent irrigation requirement.

Table 2. Farm Power Availability and Average Productivity of Food grains in India in 2001

S.No.	Name of the State	Farm Power Availability (kW/ha)	Food grain productivity (kg/ha)
1	Punjab	3.50	4032
2	Haryana	2.25	3088
3	Uttar Pradesh	1.75	2105
4	Andhra Pradesh	1.60	1995
5	Uttranchal	1.60	1712
6	West Bengal	1.25	2217
7	Tamil Nadu	0.90	2262
8	Karnataka	0.90	1406
9	Kerala	0.80	2162
10	Assam	0.80	1443
11	Bihar	0.80	1622
12	Gujrat	0.80	1169
13	Mdhya Pradesh	0.80	907
14	Himachal Pradesh	0.70	1500
15	Maharashtra	0.70	757
16	Rajasthan	0.65	884
17	Jharkhand	0.60	1095
18	Jammu & Kashmir	0.60	1050
19	Orissa	0.60	799
20	Chhattisgarh	0.60	799
	All India	**1.35**	**1723**

Agriculture in Orissa, on the other hand, has been typically subsistence in its character. Use of fertilizer is much less than the recommended doses for high yielding varieties of paddy, while it is practically nil for local varieties. Use of plant protection chemicals has been also nil. Both the factors contribute to low crop yield levels and consequently, low energy use efficiency. Yield of paddy has been about half that of Punjab, while the energy use has been about one-third.

The average energy consumed in production of some major crops in India is shown in **(Table 3)**. Sugarcane and potato are the most energy-consuming crops, while sugarcane-sugarcane and paddy-wheat-maize are most energy consuming crop rotations.

In a study in Madhya Pradesh (MP) paddy cultivated under rainfed condition used one-fourth energy and gave one-third yield as compared to that of Punjab. Same situation was noticed for most major crops in MP, indicating that to achieve higher crop productivity, a sizeable rise in energy investment has to be assured.

Table 3. Energy use and energy productivity of some major crops in India

	Crop	Total energy, MJ/ha	Energy productivity (kg/MJ)
Food grains	Paddy	13076	0.239
	Wheat	14657	0.196
	Maize	9956	0.215
	Sorghum	4745	0.200
Pulses	Green Gran	4315	0.118
	Black gram	3870	0.105
	Bengal Gram	5464	0.190
Oilseeds	Mustard	8051	0.119
	Soybean	6382	0.171
Cash crop	Sugarcane	59192	1.039
	Cotton	9972	0.094
	Potato	31352	

Source : AICRP Energy Requirement (ICAR)

Regional Variation in Energy Use

Paddy

Data on energy used in cultivation of paddy obtained under All India Coordinated Research Project on Energy Requirement in Agricultural Sector between 1986 and 1992 are given in **Table 4**. For irrigated paddy cultivation, the energy need is higher (about four times) due to use of irrigation and higher dose of fertilizer than under rainfed condition. Due to uncertainty of monsoon, the use of fertilizer in rainfed areas is considerably less. For intensive agriculture in Punjab and Western-UP, which are well mechanized, use renewable energy only 13-26%.

The total energy use in paddy cultivation in irrigated area ranged between 17500 to 33500 MJ/ha, while in rainfed areas it ranged between 6,600to 11100 MJ/ha. The pattern of

Table 4. Energy Uses for transplanted paddy cultivation in different areas

Energy resource	High yielding zone irrigated	Medium yielding zone irrigated	Medium yielding zone zone rainfed
Direct energy, MJ/ha	14716	7586	7139
Indirect energy, MJ/ha	18803	9916	3990
Total energy	33519	17502	11129
Energy productivity, kg/MJ	0.139	0.191	0.250

Source : AICRP on Energy Requirement

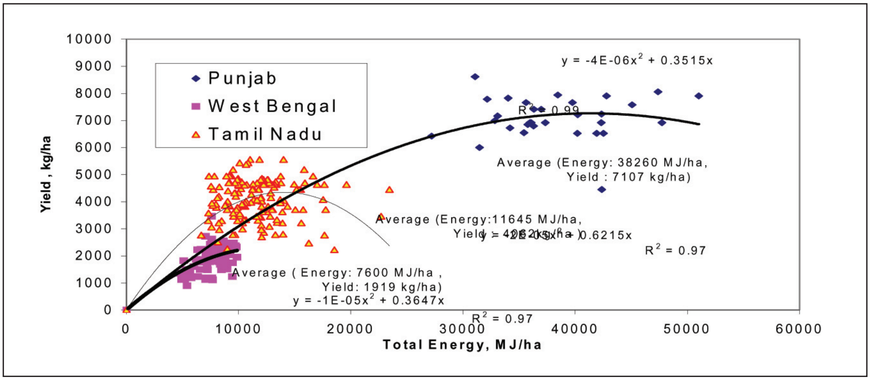


Fig. 3. Variation in energy consumption and yield of paddy cultivation in 3 states having different level of mechanization

variation of energy use for kharif paddy cultivation under different cultivation practices in representative villages of Punjab, West Bengal and Tamil Nadu during 1997-98 is shown in **Fig.3**. Energy intensity in Indian agriculture is high primarily due to lower productivity. With increase in mechanization level from traditional to mechanized system, the energy consumption increased at a much higher rate (3.49 times) as compared to increase in yield (2.76 times).

Wheat

Wheat is mostly raised under irrigated conditions. In small areas where soil moisture is available or rain water is conserved, it is cultivated under rainfed conditions too. Total energy consumption in irrigated areas of Punjab and U.P was about 18,000 MJ/ha (**Table 5**). Under rainfed condition, total energy consumption in States of Punjab, U.P and M.P ranged between 4,500 to 13,000 MJ/ha. Use of diesel and electricity in irrigated areas constitutes about 60-80% of total direct energy use and about 40% of the total energy

Table 5. Energy consumption in wheat cultivation in different States

	Punjab	West Bengal	M.P.	Uttar Pradesh
Direct energyMJ/ha	8739	10000	4690	7816
Indirect energy, MJ/ha	10142	4000	3806	9670
Total energy, MJ/ha	18881	14000	8496	17486
Yield,kg/ha	4183	2450	2100	4516
Energy intensity (MJ/kg)	4.51	5.71	4.05	3.87
Non-renewable: renewable	6.1:1	2.4:1	1.02:1	6.3:1
Energy ratio	5.78	2.34	7.22	6.54

Source : AICRP Energy Requirement (ICAR)

consumption. In areas of intensive agriculture, renewable energy consumption is low about 14% of the total compared to rainfed conditions as in MP where it is over 90%. In intensive agriculture, irrigation required about 40%, harvesting and threshing about 30% and seedbed preparation about 17% of total operational energy. Energy use for wheat cultivation in typically rainfed condition ranged between 6,500 to 14,000 MJ/ha and under irrigated condition 14,000 to 19,000 MJ/ha

Energy Requirement of PHT & VA Sector

PHT & VA are vital for realizing optimal returns and employment from agricultural produce and by-products. Data base on energy use in post-harvest management (PHT) and value addition (VA) activities are scanty and inadequate. PHT & VA activities are at low key and as a result, share of energy use in this sector is rather low. It can also be said that availability of electricity at affordable prices in the rural areas is a prerequisite for development of these activities so vital for additional income and employment to rural people. Limited studies do indicate that there is room for conservation of commercial energies in processing, handling and storage of agricultural products by supplementing and substituting with renewable energy sources both for process heat and shaft power. R&D efforts should be directed in this direction. **Table 6** gives energy requirement for selected agro-processing industries. Demand for diesel and electricity in this sector is going to rise about 1.4 Mt every five year and 1.25 Mt oil equivalent (OE) of electricity.

Energy in Rural Living

The amount and quality of energy use is a good indicator of quality of life. There is a great deal of variability in amount and quality of energy use in rural homes in the country. Massive rural electrification programme has brought electrical lamps and fans, refrigerators, TV and radio sets in the rural homes. But due to poor power supply, situation is far from satisfactory. Refrigerators and LPG cook stoves have reached primarily to homes of rural

Table 6. Energy requirement of some agro-processing industries

Industry	kWh/t of raw material	Steam/t of raw material(t)
Flour mill	20.0	-
Rice mill (parboiled)	22.5	0.4
Dal mill	20.0	-
Sugar mill	36.0	0.4
Oil mill (refined oil)	270.0	1.0
Oil mill (filtered oil)	75.0	0.2
Milk plant (mixed products)	464.0	1.6

elites. However, vast majority of rural households depend upon traditional practices of collecting firewood or making dung cakes for fuel, fetching drinking water from distant places, cooking food in single or double pot cook stoves. Often drinking water used is not potable. Some rely on kerosene for cooking and lighting. However, programmes of Rural Development and that of MNES are trying to improve the situation, but the pace of change is very slow. Rural kitchens are unhygienic and ladies suffer from smoke, and particularly from pollution health hazards. Solar home models have been developed.

As a result of R&D in the country, efficient cook stoves (25% thermal efficiency) have been developed and are under promotion through MNES and state development agencies. Renewable sources of energy have been developed for rural living which needs to be exploited.

RENEWABLE ENERGY SOURCES

Potentials of Renewable Energy

The available annual potentials of renewable energy resources in the country are estimated as under:

Wind power	:	20,000 MW
Micro/Mini/Small Hydel power	:	10,000 MW
Biomass/Bio energy	:	17,000 MW
Ocean Thermal Energy	:	50,000 MW
Tidal Power	:	9,000 MW
Solar Energy	:	33,000 MW
(1% area @20 MW/km^2)		

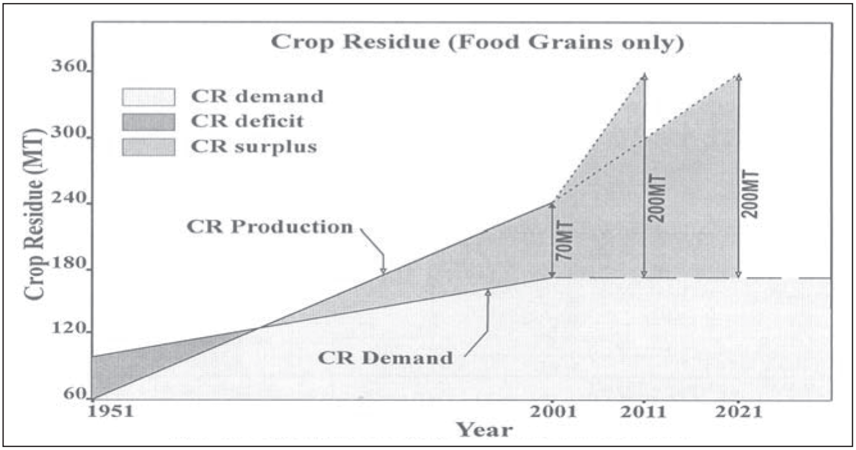
The Ministry of Non Conventional Energy Sources (now Ministry of New and Renewable Energy) of the Govt. of India is planning to have renewable energy sources contributing to about 10% of the total electrical power generation in the country by the year 2007. Renewable power generation has increased to 10500 MW in India. Looking to the demand potential, process of harnessing renewable sources of energy needs to be accelerated. There have been path breaking achievements especially in wind energy and solar thermal energy systems. India has a policy to deploy renewable energy for grid and off-grid power. International cooperations with leading countries are being developed to accelerate the process.

Wind Power: A wind power density of 200 W/m^2 or more is considered feasible for development of wind farms. In India, it ranges between 20 – 721 W/m^2. Coastal areas and pockets in inland have favourable wind power density. Globally, wind power industry is growing at the rate of about 24% but is likely to be reduced to 19% by 2010.

Micro/Mini/Small Hydel: India is already exploiting small hydel power aggregating to about 175 MW. Another 185 projects aggregating to 188 MW are under construction. It is believed that there are about 0.2 million water mills (working or defunct) in the Indian Himalayas. The Himalayan Energy Services Company (HESCO) has sponsored WMA (Water Mill Association) in Chamoli representing Gharat- owners in the region. A multi-purpose low-cost cross flow turbine (6kW capacity) has been introduced in the region that operates a rice huller, oil expeller, and generator.

Biogas: Efforts to use biomass for energy purpose is multi pronged. The earliest initiative was on bio-methenation of cattle dung that gave quality fuel as biogas for rural kitchens, while the spent slurry (fresh or dried) was used as valuable plant nutrients. Biogas applications were later diversified for illumination and for operation of irrigation pumping sets using dual fuel engines. As a result of indigenous R&D, new designs of biogas plants have been developed using cattle dung and alternate feed stocks. The Ministry of New and Renewable Energy has given priority to popularization of family and community biogas plants. As a result, India today has about 3 million biogas plants installed in the rural areas.

Crop Residues: India annually produces about 400 Mt of crop residues (**Fig. 4**), which are often underutilized. In areas like Punjab and Haryana, paddy straw is incinerated for quick disposal in order to prepare the fields ready for the next crop. Besides, sugar mills produce large quantity of bagasse. By the end of December 1998, 28 power projects were commissioned (with aggregate installed capacity of 141 MW), while another 27 projects are under construction (adding 180 MW capacity) through utilization of the residues as fuel. At present, indigenous technology based gasifiers (upto 500 kW capacity) using agricultural byproducts are being manufactured in India. Energy potential of crop residues



Source : Pathak B.S. (2005)

Fig. 4. Development of crop residue surplus

like rice and wheat straw, sugarcane trash, stalks of other crops have remained untapped. Crop residue surplus is more in irrigated areas. Agro-processing residues are equally important; 45 Mt of bagasse, 25 Mt of rice husk, 2 Mt of groundnut shell, etc. Many sugar mills have gone for co-generation using bagasse. With increase in agricultural productivity there is steady increase in crop residue surplus. Agro-processing industries are also using biomass as fuel for operating high pressure boilers through adoption of appropriate technologies. Sugar, paper and textile industries are already implementing co-generation of power from organic residues. Technology is available for production of biogas from wilowdust, a byproduct of textile industry. Annual availability of wet animal dung is about 960 Mt. Biomass conversion routes are many.

Fuel wood for cooking: In Indian village eco-system, about 80% of the total energy is used by the domestic sector, of which 80% is mostly used for cooking derived from fuel woods, crop residues and livestock solid wastes. Traditional cooking stoves used in rural homes have thermal efficiency of about 10%. About 30 million improved cooking stoves with thermal efficiency exceeding 20 per cent have been installed to save precious fuel wood The participation of rural women has been the keyword in successful implementation. Conventional kitchens create health hazard due to fumes / smoke. Often rural women have to go through drudgery, fetching drinking water from long distances and gathering fuel wood and making dung cakes. Crop residues and processing wastes can be converted into briquetted fuel with better burning characteristics as well as into charcoal which avoids excessive smoke. Technologies are available to convert crop residues into briquetted fuel.

Solar Energy: India receives about $5x10^{15}$ kWh/year of solar energy. Potential of use of solar energy for cooking, water and air heating, crop drying, desalination, refrigeration, and power generation are being tapped. Solar cookers, solar water heaters and solar dryers are now commercially available in India. There are about 40 BIS (Bureau of Indian Standards) approved manufacturers of solar water heater with an aggregate capacity of 100,000 m^2 per year. However, the present annual sale of industrial water heaters (upto capacity of 240,000 lpd of hot water) and domestic systems (50-100 lpd) is of the order of 50,000 m^2. The Ministry of New and Renewable Energy is scheduled to install a 140 MW capacity solar power plant in Rajasthan.

Photovoltaics: India is presently the second largest manufacturer of solar photovoltaic panels based on crystalline silicon solar cells. Nine firms manufacture solar cells and another 21 produce solar panels. The solar panels have found use in industrial as well as agricultural and rural sector. India has one of the largest solar power utilization programme leading to installation of 0.6 million systems with an aggregate capacity of 39 MW for more than 30 types of applications. A massive expansion of the programme is contemplated. Inspite of high capital investment, solar water lifting systems have been found to be useful in areas where electricity has not reached. About 50,000 solar panels of 560-900 W capacity have been installed or are in the process of installation for operating DC/AC motor operated submersible pumps.

Solar Home Systems: There are several home systems under promotion featuring 1,2, or 4 CFL. It is also possible to run a small DC fan or 12V – DC television. PV modules of 18,37 or 74 W capacity with lead acid battery of 20, 40 or 75 AH these systems can function upto three cloudy days.

Tidal Power: It is estimated that Gulf of Mumbai has a tidal power potential of 7000 MW, and Gulf of Kutch and Sunderbans each have a potential of 1000 MW. Efforts have been initiated to tap this potential. A fraction of the energy locked in the oceans could meet world's entire electricity needs. However, as of now only 14 countries operate tidal or waive power stations, most are tiny and expensive. Tidal power projects have been in use in China and France or over 40 years.

ELECTRIC POWER SCENARIO IN INDIA

Electrical power in 21st century is a basic human need for economic activities, education, health care, transport and living. There is clear nexus in electrical power and quality of life. Government of India and in turn state governments, have created infrastructure to generate and supply electrical power. GOI as back as 1948 passed Electric (Supply) Act which entrusted the task to State Electricity Boards (SEBs). This commitment was further reinforced by new Electricity Act (2003). Upto 1970s, SEBs created capacity which was far too short of the requirement and as a result, central public sector units – National Thermal Power Corporation (NTPC) and National Hydroelectric Power Corporation came into existence which increased the

Table 7. Total installed capacity of electric power generation in India

Sector	MW	%
State Sector	70,447	57.1
Central Sector	39,908	32.3
Private Sector	13,187	10.6
Fuel		
Coal	68,308	55.4
Gas	12,430	10.0
Oil	1,201	0.9
Total thermal power	81,939	66.3
Hydroelectric	32,135	26.0
Nuclear power	3,310	2.7
Renewable	6,158	5.0
Total installed capacity	1,22,542	100.0

Table 8. Per capita electricity consumption in selected countries

Country	Per capita consumption, kWh
USA	13,456
Japan	8,612
UK	6,614
Russia	6,062
Brazil	2,183
China	1,484
India	665

Source: UNDP Human Dev. Report, 2005

capacity manifold. At the time of Independence (1947) installed capacity was only 1,362 MW with per capita consumption of only 15 kWh which has increased to 122540 MW providing 592 kWh per capita. At the time of Independence, only 1500 villages were electrified, while today 4,75,000 (81 %) villages are electrified. While connectivity is there, but in terms of power availability it is far from satisfactory. Bulk of the rural households (56%) is still without power (2004-05). To assist the states, Centre provides expertise and services of NTPC, NHPC, PGCIL (Power Grid Corporation of India Ltd, and DVC (Damodar Valley Corporation). Rural Electrification Corporation (REC) canalises financial resources.

Inspite of tremendous progress made in electric power generation (**Table 7**) and per capita electric consumption in India is far too low (**Table 8**) compared to developed and lead developing nations. Estimated shortfall is 9.1 %. Situation of power supply is not satisfactory and entrepreneurs are forced to have standby power generator which provide electricity at 2-3 times the grid power cost. Paucity of electric power has thwarted rural entrepreneurship, rural agro-processing and value addition activities.

ENERGY SAVING PRACTICES

Efficient Mechanization: Use of appropriate power and matching implements operating at rated capacity saves energy. Underloading of engine, common phenomena in India, has been observed to induce 20 to 30 % wastage of fuel. Simple care of maintaining thermostat valve of radiator saves period of cold running of engine and saves fuel.

Conservation Tillage: Studies have indicated that it is possible to raise good crop stand with reduced tillage, minimum tillage, and no-tillage if desired plant population can be established, nutrients applied and weeds are chemically or otherwise controlled. Improved sowing equipment as strip-till drill has been found to save 50 to 70 % fuel in field preparation and sowing operation. Use of improved tillage implement as disc harrow-cum-puddler has been found to save about 45 % of energy in wheat and paddy cultivation in Punjab as compared to conventional implements. Use of energy efficient tractor operated rotavator in light soil can save about 20 to 30 per cent of energy as compared to cultivator and disc harrow. Zero-till drill and raised bed planters save considerable amount of diesel used in seed-bed preparation and irrigation, respectively.

Water Management: Lifting of irrigation water, its conveyance and application in irrigated farming are commercial energy intensive operations. About 83% of diesel oil and electricity are used for stationary farm operations, irrigation accounting for 75%. The operational efficiency of irrigation pump sets generally varies between 25 to 60 per cent due to improper selection, mismatch of drive units, excessive long piping systems with avoidable use of bends, poor pipe fittings and faulty footvalve. Use of flat belt for power transmission reduces system efficiency by 5 to 15%. Specific fuel consumption of stationary diesel engines commonly used ranges between 200 to 350 g/bhp-h, which is considerably high. BIS certified pumps work with 8 to 15 % higher efficiency as compared to the local ones. Similarly, use of plastic pipes with low friction co-efficient as compared to mild steel or galvanized iron pipes can improve overall pump efficiency. For areas requiring low water lift, indigenous low lift high discharge propeller pumps are better options than centrifugal pumps. Sprinkler and drip irrigation application systems save about 20 to 40% of irrigation water over flood irrigation method with substantial yield advantages. Laser land leveling, zero-till drill and raised bed planting save considerable amount of water (15-30%) and energy besides yield advantages.

Weed Management: For weed control, chemical application has been found to be more effective and energy saving. Improved equipment as wheel hand hoe, animal and tractor operated cultivators have proven to be energy efficient through saving energy by about 70% as compared to physical weeding or with *khurpa*, a traditional hand tool used in squatting position, in addition saving time. Excessive weeds damage yield, share and waste the inputs applied.

Harvesting and Threshing: Harvesting of crops and subsequent handling, threshing and separation of grain and straw are energy intensive operations. More than 16 thousand combines are presently in use in various parts of the country. Threshing of crops are mostly done by threshers. The population of threshers is about 3.247 M in the country. However, in hilly areas threshing is still done manually. Farmers generally use a 35 hp tractor for operating the thresher, which otherwise can be done by 7.5 to 15 hp diesel engine or 5 to 10 hp electric motor. Tractor engines are, therefore, used on part-load with decreased fuel efficiency. Harvesting by combine requires about 930 MJ/ha and saves about 40 to 55% energy in paddy harvesting over other methods, taking harvesting, threshing and cleaning together. Digging of crops like groundnut, and potato needs much less energy if soil is in friable condition.

Rural Living: Rural home activities – cooking, fetching water and fuel wood, etc. are energy consumer in village eco-system consuming 69% - 85% of total energy. Energy saving and supplementation in this sector is thus, also of primary importance to energy management. Cooking is the main energy consuming activity in domestic sector. Improved cook stoves have been found to decrease fuel consumption by 19 to 28 % for fixed and portable models with annual fuel wood saving in a 5 member household of about 275-500 kg, respectively. Use of pressure cookers conserves energy as well as nutrition. Use of solar cooker can also save 5-19 % of energy, provided its use can be made more acceptable. Pre-soaking of rice and pulses can reduce cooking time by 5 –30 %. Women being the ultimate dispenser of most of energy use in household activities, development of awareness among them on measures of energy conservation would prove to be useful.

Bio-fuel and Bioethanol: India not being richly endowed with petrochemicals and about 70% of petrochemicals products used being imported and crude oil prices steadily rising, it is constrained to look for alternate sources of liquid fuels for IC engines. Govt. of India has launched an ambitious project on bio-fuels – biodiesel, ethanol blending of petrol and now it is official to have 5% ethanol blended petrol. Wastelands conserved are being put under *pongamia* and *jatropha* plantation for producing biodiesel. In some states, especially southern states it is successful. USA has gone for biofuel (ethanol) from corn which is supposed to be responsible for steep rice in food prices.

RECOMMENDATIONS

1. **Energy Availability and Use:** Agriculture is basically an energy conversion activity. It is both producer and consumer of energy. It consumes large quantities of energies directly through animate power sources of men and draft animals, diesel engines, electric motors, tractors, power tillers, other self propelled equipment, fuelwood and other biomass. It also uses energies indirectly in the farm of seeds, manures, fertilizers, pesticides and other chemicals, implements and machines, etc. There is close nexus between energy and agricultural productivity. The following measures need to be taken.

   - Energy, power and inputs need to be optimally provided and utilized for efficient and profitable intensive agriculture
   - Energy adds to the cost of production, and therefore, it should be efficiently utilized, wastages minimized based on R&D results; alternate cheaper and renewable sources progressively adopted.
   - We need to target farm power availability of 2 kWh/ha and increased as mechanization advances.

2. **Optional Use of Animate Power:** Animate energy use can be enhanced through ergonomically sound matching equipment and rational work- rest cycles.

   - Animate energy use be increased for improving sustainability of draft animals through more efficient implements for rotory mode of operations, grinding, chaff cutting, etc., short distance movement of men and material.
   - Manual and animal drawn equipment be made ergonomically sound minimizing fatigue to operators and draft animals.
   - Work-rest cycle of animate system be rationalized and optimal conditions established and awareness created.

3. **Mechanical Power Sources and Their Use:** Since 1970, tractor production and use has increased @9.8% p.a, power tillers 12.7%, diesel engines @ 4.9%, power sprayers and dusters @ 6.7%, which need to be fully utilized.

   - Annual use of tractors be targetted to 1000 h/y (currently about 600h) and use of other power operated equipment be increased through custom hire.
   - Advisory services, on-farm demonstration and training facilities be developed in departments of agriculture and horticulture, etc. for promoting appropriate farm mechanization.

- Custom servicing involving educated rural youth be developed to avoid unnecessary ownership of costly equipment needed by the farmers.

4. **Electric Power Supply and Use:** Electricity is most convenient, clean and efficient form of energy for any stationary operations, illuminations, aeration and ventilation, processing and storage, etc. Agriculture and rural sector, in general, deserve due share of electricity.

   - More grid power be made available to the farmers for agriculture, agro-processing and living.
   - Windmills/ wind power generation farms be installed in areas suited for wind power generation both for stand alone applications and grid power.
   - In hilly areas mini and microhydel power units be popularized.
   - Stand alone power units run on producer gas, biogas, plantations and other biomass need to be developed.

5. **Application of Renewable Energy Sources (RES):** As a result of R&D on RES in India, a number of gadgets have been developed and found fieldworthy that need to popularized conserving and substituting commercial energy that are becoming steadily costlier and scarce. Rural areas are better placed for using RES.

   - Briquetting of crops residues yield fuelwood substitutes with superior burning characteristics. Briquetted fuels from crop residues be popularized.
   - Energy plantations on non-arable lands can provide fuel wood/ charcoals and feedstock to producer gas gasifiers.
   - Improved smokeless *chulhas* and *sigdis* of higher efficiencies above 20% need to be promoted which can save 15-20% of fuelwood.
   - Gassifiers run on wood billets, crop and processing residues need to be popularized for shaft power as well as process heat reducing dependence on fossifuel and electricity.
   - Solar cookers, solar water heaters, solar dryers and photvollatic gadgets both domestic type as well as community/ commercial type need to promoted and progressively refined for greater efficiency and economy.
   - Family and community size biogas plants run on cattle dung and alternate feed stocks should be promoted, matching with the raw material availability.

- Incineration of crop residue for disposal should be substituted with biomethanation for energy and manure, composting, and vermi-composting.
- Stand alone power units run on crop residues can be useful in promoting rural agro-processing units and hence, deserve promotion with incentives.
- Decentralized bio-fuel/ biodiesel units should be developed for use in agriculture, specially in remote areas.

6. **Energy Efficient Agriculture:** Integrated efforts are needed refining cropping and crop rotations, adopting of precision farming equipment and practices, plugging wastage in direct and indirect energy use, conserving commercial energies, supplementing and substituting with RES.

   - Use of equipment that precisely meter and apply inputs be promoted which can effect economy in seed, fertilizer, pesticide and irrigation water use, and reduce unit cost of production and enhance profitability.
   - Energy efficient crops and crop rotations that are well suited to agro-climatic situation and are in demand in the market, be preferred.
   - Adopt equipment and practices that conserve energy such as Zero-till Drill, Raised-Bed Planter, Seed-cum-Fertilizer Drills and Planters, Rotovator for seedbed preparation, mechanical rice transplanter, drips and sprinklers and their variants for irrigation.

7. **Energy for PHT and Value Addition:** Scope of agriculture has been widened addressing production to consumption gamut of activities for sustainable livelihood for rural homes. Inadequate and nondependable grid power supply impedes rural entrepreneurship.

   - Biomass based stand alone power units can alleviate this constraint. These be extended to targeted beneficiaries.
   - Grid power connectivity should be provided to rural entrepreneurs to promote PHT&VA for additional income and employment.
   - Processes that need cyclic wetting and drying, should be avoided to conserve energy.
   - Adopt PHT & VA practices, that can run on locally available solar wind and micro-hydel power, etc., should be preferred without sacrificing profitability and viability.

8. **Energy for Rural Living:** In a rural ecology about 80% of the total energy use goes to domestic sector, of which 80% goes in cooking of food. Efficient cook stoves and cooking practices conserve energy.

- Nation wide adoption of efficient smokeless cookstoves integrated with water heating using waste heat/ fluagasses.
- Awareness be created about efficient cooking practices- pressure cooking, soaking of rice and *dal* before cooking.
- Popularization of domestic as swell as community size biogas plants where cattle dung and alternate feedstocks are available, which can make rural kitchens hygienic.
- Adoption and popularization of efficient and convenient solar cookers both for family and community use, be taken in a big way, specially on rural areas.
- Solar water heaters integrated with rural homes to have heated water without use of fuel, be popularized all over the country.
- Popularize photovoltaic domestic and community gadgets for water supply, illumination, and operation of domestic equipment like radio, TV, refrigerator, etc.

9. **Energy Management:** Precise assessment of demand, identification of wastages and their amelioration at the same time assure adequate availability of energy and power.

- Energy audit should be undertaken every five years, assessing demand, supply, and consumption covering agriculture, agro-processing, and rural living
- R&D developing commercializing energy efficient equipment and practices backed by promotional schemes with and without financial incentives.
- Reclamation of plant nutrients from farm, community, market yards and community/ hospital kitchen residues through biological pathway- biogas, compost, vermicompost, etc.
- To bridge rural – urban divide and prevent migration of rural people to urban areas, energy and power in required form and quantity is a basic necessity along with transport and water supply.

CONCLUSIONS

Agriculture and agro-processing are energy intensive. Traditional sources of energy, power and inputs do not meet requirements of modern intensive agriculture that achieves production and productivity levels, which assures food and nutrition security of the country. Use of commercial energies, directly and indirectly, are inevitable. Indigenous R&D on energy studies have established that specific energy consumption per unit of productivity of Indian agriculture is higher than in the developed nations and is on the rise trend. It raises unit cost of production and reduces competitiveness in global market. Energy efficient agricultural practices and equipment in rural areas like raised bed farming and irrigation in furrows, use of Zero-Till Drill in rice-wheat rotation, rotavators, drips, sprinklers and automated irrigation and fertigation systems can conserve commercial energy. Use of biogas, biofuels, solar cooking, solar water heating, solar crop drying, photovoltaic gadgets, wind and hydro electric power, etc. can help in meeting energy needs partly. Refinements in cropping and crop-rotations can be energy saving. Non-availability of grid electrical power impedes rural agro-processing and entrepreneurship which can generate additional income and employment, widening livelihood base essential for socio-economic development. To address to the energy issues and find sustainable solutions a Brain storming was held at Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar (J&K) on October 25, 2007. Rural energy scenario was thoroughly discussed and emergent recommendations, that can provide sustainable solutions, are documented in this policy paper.