Chapter 1

Introduction

The ecology and the universe, the matter and the energy are all combined, Integrated, interactive and keep growing exponentially. In the physical ecosystem the two prime movers are ***matter and energy***; more complicated, a system thereafter, is the biological ecosystem wherein the prime movers are ***genetics and metabolism***. And thereafter, comes the next and most important ecology i.e. **Social ecology** wherein the prime movers are, ***intelligence and motivation***. So this is a hierarchy exposition of matter and energy and energy comes as the basic instigation to earn dynamism, transmission and transformation.

So far and so on the extension paradigm is basically based on the transfer of technology. It is basically linear and monolithic approach, as yet to cherish a denial to the existence of the non-linear functioning of the system and its cybernetics. The decline of agricultural productivity cannot only be relegated to a genetic degradation of variables or levels of impurities in fertilizer. As usually as we are doing, we seldom delve into the complicated interaction between matter and energy which deciphers the instincts and inspiration of farmers for the productive function of factor production. A productive farm is always energy wise, balanced, composed, agile and resilient. This means the factor production in a farm have been well audited and accentuated in terms of energy input and energy output quotient. If the factor production of a farm is so constantly extravagated i.e. more of energy emission and less of energy trapping, then it is sure to lose its energy balance and the system will turn „cooler" with the loss of farm"s energy and in no way, the present level of productivity can be retained or upgraded.

ISBN: **978-93-85822-54-4**

Social ecology through its integrative and orchestration function, can rationalize the energy expenditure on agriculture in the forms of:

i. Application of agricultural chemicals like fertilizers, pesticides etc.
ii. Handling of factor production with higher proficiency in terms of economic health
iii. Generation of values in terms of calorie values, quality contents like proteins, minerals and therapeutics and making the volume of food production affordable and accessible to people of marginal sections.
iv. The model on energy in social ecology has got three basic considerations –
   a) Flow of energy from one small niche in between can be called social metabolism.
   b) The flow of capital into this system of entrepreneurship and intensity of rotation to ultimately characterize enterprise product and outcome.
   c) Conservation of energy through considering the renewability level of different energy forms entering the system.

The energy consumption level in India especially in the agro-ecosystems followed by small and marginal farm holdings, has been around 85% of total 130 million farm families in India generating 259 million tonnes of food grain that include a record production of 106 million tonnes of rice, 95 million tonnes of wheat, 22 million tonnes of maize, 17 million tonnes of pulses, about 30 million tonnes of oilseeds, 210 million tonnes of horticultural production, 180 million tonnes of milk and 8.7 million tonnes of fish (2011-12) has got tremendous implication and needs to be added against total volume of energy consumed in a positive balance or a negative balance either.

So, the new age extension science will increasingly be aiming at energy auditing, energy designing and energy management. Even with plenty of fertilizer and fertility of genomes cannot usher in the productivity unless the energy backup has been properly maintained.

With this background, the present study envisages to generate a model on farm metabolism; ultimately the metabolic function of farm can be audited, estimated and esteemed.

The transformation of agriculture and its mellifluent behaviour is the common nature for the new age agriculture. There is a clear swing from per hectare biological production to per hectare value generation with ecological pursuits and dimensions.

Socio-economic systems depend on a continuous throughput of materials and energy for their reproduction and maintenance. This dependency can be seen as a functional equivalence of biological metabolism, the organism‟s dependency on material and energy flows and we therefore, employ the concept of "social metabolism". Contrary to the biological notion, however, the socio-ecological paradigm links the material and energy flows to social organization; recognizing that the quantity of economic resource use, the material composition and the sources and sinks of the output flows are a function of socio-economic production and consumption systems. These systems are highly Variable across the time and space. We describe the social systems according to their metabolic profiles in relation to their economic and technological structures, as well as, their demographic governance and information patterns.

Use and Management of Energy in Indian Agriculture

Energy use in agriculture has been increasing since Green Revolution in the late sixties increasing use of high yielding seed varieties, synthetic fertilizers, agro-chemicals, as well as diesel and electricity in farm operations. The pattern and rate of growth of demand for energy source is influenced by a number of factors such as increasing population, growing urbanization, rising household income, changing life-style and structural changes taking place in the economy. Increase in land productivity and efficient diversification of agriculture for better economic return to the producer call for significantly higher level of energy input to agriculture. Agricultural experts all over the world have marshalled ample evidence to support that energy use per hectare has direct bearing on the crop yield. The Indian agriculture has witnessed a tremendous transformation since Independence, particularly owing to the 'Green Revolution' of the sixties. As a result, the food production has increased about more than four-fold,

ISBN: **978-93-85822-54-4**

leading the country toward self-reliance and food security. Energy is central to national development process and to provide major vital services that improve human condition – fuel for cooking, light for living, motive power for transport and electricity for modern communication. In agricultural sector, its use is in every form of inputs-seed, fertilizer, agro- chemical for Plant Protection, machinery use for various operations for crop production and processing, household activities and transport.

Energy Use in Indian farming:

Agriculture in India has gone into more or less total transformation from organic to inorganic agriculture. Increasing use of commercial energy has made agriculture move with fast stride. Energy as an input is attaining higher demand with the growth of agriculture production. A significant aspect of agriculture and energy is the interactive relationship between energy and other agricultural production input. Agricultural productivity is closely linked with the energy. There is directly energy input (derived from mean, animal, electric motors, engines, power tiller and tractors) required for seedbed preparation, sowing or panting, inter-culture weed control, irrigation, harvesting and threshing, transportation, and there are indirect energy input (in the form of seed, fertilizers, organic manures, pesticides, weedicides, growth regulators, machinery, and structures) Energy is the prime mover of economic growth, and is vital to sustaining a modern economy and society. In Agriculture energy is the most important input that promotes sustains and directs both production and productivity but Indian farmers are more input illiterate and less energy educated. The indiscriminate consumption of energy, as has been reflected in water management, soil and nutrient management, even in part of processing agriculture, will lead to a catastrophic ecology in Indian farming. Commercial energy use in agriculture has been increasing since Green Revolution with increasing use of diesel and electricity in farm operations. Total commercial energy use in agriculture increased nearly five-folds, with growth rate of 11.8% between 1980-81 (1.6 m tonne) and 1994-95 (7.7 m tonne), but the share of agriculture in total commercial energy consumption in the country increased marginally from 2.3 to 5.2% during the same period. Electricity is one of the main sources of commercial energy in production agriculture. The share of agriculture has increased from 3.9% of total consumption in 1950- 51 to 29.6% in 1993-94. Agriculture itself is an

ISBN: **978-93-85822-54-4**

energy user and energy in the form of bio-energy. Energy use in agriculture has developed in response to increasing an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labour-intensive practices, or both. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution which need varying amount of commercial and non-commercial energy source. Factors that have contributed to increase in agriculture production are technology advancement, improved irrigation practices and increased area under irrigation, improved seeds, use of fertilizers, use of pesticides, improved agricultural implements and machinery, agricultural credits and rural banking and improved marketing and support price.

Energy Use in Rural Household:

The Research and Development programmes in Energy Management in Agriculture are being implemented through the three All-India Co-ordinated Research Projects on Energy Requirement in Agricultural Sector, Utilization of Animal Energy and Renewable Energy Sources. Besides this, research is also being conducted in the Agricultural Energy and Power Division of the CIAE, Bhopal, and Agricultural Engineering Divisions of CAZRI, Jodhpur and IARI, New Delhi. Research work related to Energy Management in Agriculture is on improving efficiency and utilization of conventional sources of energy like jamun, animal power tiller, tractors, oil engines/electric motors and self propelled machines used in agriculture.

Work is also being done on using renewable sources of energy in agriculture like biogas, solar energy, wind energy, producer gas, and utilization of biomass for energy purposes. Work is also being done on assessment of energy needs for different level of production for crops, agro-industries, allied agricultural sector, and identifying energy efficient equipment/machines to economize on energy requirements in agricultural sector .Cooking alone consumed 81 -94% of energy, Conservation of cooking energy is thus an imminent need. Improved cook stoves were found in that research to decrease fuel consumption by 19 and 28% for fixed and portable models, thus saving annual energy, in a 5 member household, equipment to 284 and 507 kg respectively. Smokeless cook stoves consume

ISBN: **978-93-85822-54-4**

24% less fuel (with thermal efficiency of about 17%), are time saving and less pollutant for cooking as compared to traditional cook stove.

Energy Requirement:

The average availability of power increased from 0.31 kw/ ha in 1961 to 1.08 kw/ ha in 1995. Power availability in Punjab, where productivity is highest is about 3 kw/ ha. Time series power availability on Indian farms is given in a Table.

Table: Time-series Power Availability of Indian Farms

Year	Total power availability	Animate	Source wise % Mechanical	Electrical
1961	0.31	94.9	3.7	1.4
1971	0.36	79.2	13	4.5
1981	0.63	48.2	32.3	19.5
1991	0.92	34.5	34.7	30.8
1995	1.08	25.9	40.8	33.3

Anticipating major upward shift in the energy demand and energy use pattern in the agricultural sector, the Indian Council of Agricultural Research in 1970-71 initiated an All-India Co-ordinated Research Project entitled, Energy Requirements in Intensive Agricultural Production, later renamed as **Energy Requirement in Agricultural Sector**.

The Project took-off with five co-operating centres and later expanded to a total of 10 centres located at PAU, Ludhiana, GBPUAT, Pantnagar, TNAU, Coimbatore, JNKVV, Jabalpur. CR1DA, Hyderabad, CRRI, Cuttak, ITI, Kharaupur, AAU, Jorhat, MAU, Parbhani and KAU, Trissur. In Madhya Pradesh and Punjab the average energy consumption for cultivation of major crops in villages surveyed in different agro-climatic regions are given in following Tables.In Uttar Pradesh, a positive relationship between farm size and energy consumption was observed for paddy (high-yielding) and wheat crop production but the same was not the case for sugarcane and other crops. The extent of use of animal energy generally decreased with increase in farm productivity. The extent of use of animate and mechanical energy sources did not show any definite trend with farm size although use of mechanical energy was higher on large farms.

Table: Average Energy Consumption in Crop Production in Selected Villages of Madhya Pradesh

Crop	Total energy (M.J/ha)	Yield (tonnes/ha)	Specific energy (MJ/Kg)
Sugarcane	62218	57.5	1.08
Potato	32071	0	5.35
Wheat	1167	2.34	4.99
Mustard	9279	1.04	8.92
Paddy	7833	1.98	3.96
Cotton	5805	0.43	13.50
Soyabean	5330	0.98	5.44
Sorghum	4437	1.25	3.55

Entry Levels for Interventions

It is useful to consider three entry levels for interventions as a means of examining both the energy needs for agriculture and the requirements for rural energy services in developing countries. These three levels are based on the "energy ladder" approach. For agriculture, the three-stage evolution can be considered as follows:

- Basic human work for tilling, harvesting and processing, together with rain-fed irrigation, none of which involve an input from an external fuel source;
- Then the use of animal work to provide various energy inputs;
- Finally, the application of renewable energy technologies such as wind pumps, solar dryers and water wheels, together with modern renewable and fossil fuel based technologies for motive and stationary power applications, and for processing agricultural products.

For rural energy, the needs of poor people can be considered at the following three levels:

- Energy for basic survival in cooking, lighting and space heating using traditional biomass fuels;
- Then as people move up from subsistence, alternatives to traditional biomass fuels in these applications such as kerosene and LPG;

ISBN: **978-93-85822-54-4**

- Finally, the role of enhanced energy services in rural areas using modern renewable energy and fossil fuels, for example in providing energy for small electrical appliances (e.g. lighting and radio) and the provision of community facilities (e.g. street lighting, water pumping, power for health centres and schools).

In both household and economic activities, the "energy ladder" follows and influences the "economic ladder". Attempts to alleviate poverty and to promote rural economic development and food security must be accompanied with efforts to promote the key role of energy, not simply as a goal in itself but as a vital component of these attempts.It can be seen that woodfuel still plays an important role for households even at higher income levels. In agriculture and industry, diesel engines and electricity replace human and animal work; where rural electrification is not available or is too costly, diesel generators may be used instead. Wind pumping for water extraction from wells, together with mini-hydro and, more recently, PV systems for small-scale electricity supplies for homes, farms and community buildings are possible renewable energy options. The use of these options may appear in future empirical evidence.

Table: Levels of household income and energy services

End use	**Household income**		
	Low	**Medium**	**High**
		Household	
Cooking	Wood, residues, dung	Wood, charcoal, dung, kerosene, biogas	Wood, charcoal, coal, kerosene, biogas, LPG, electricity
Lighting	Candles and kerosene	Candles, kerosene, gasoline	Kerosene, electricity, gasoline
Space heating	Wood, residues, dung	Wood, charcoal, dung	Wood, charcoal, dung, coal
Other appliances	Batteries (if any)	Electricity, batteries	Electricity, batteries
Agriculture			
Tilling	Human	Animal	Animal, gasoline, diesel

ISBN: **978-93-85822-54-4**

Irrigation	Human	Animal, wind pumps	Diesel, electricity
Post-harvest processing	Human, sun drying	Animal, water mills, sun drying	Diesel, electricity, solar drying
Rural Industry			
Mechanical tools	Human	Human, animal	Human, animal, diesel, electricity
Process heat	Wood, residues	Coal, charcoal, wood, residues	Coal, charcoal, wood, kerosene, residues
Transport			
Motive power	Human	Human, animal	Human, animal, diesel, gasoline

Energy and Agricultural Production

Agriculture is itself an energy conversion process, namely the conversion of solar energy through photosynthesis to food energy for humans and feed for animals. Primitive agriculture involved little more than scattering seeds on the land and accepting the scanty yields that resulted. Modern agriculture requires an energy input at all stages of agricultural production such as direct use of energy in farm machinery, water management, irrigation, cultivation and harvesting. Post-harvest energy use includes energy for food processing, storage and in transport to markets. In addition, there are many indirect or sequestered energy inputs used in agriculture in the form of mineral fertilizers and chemical pesticides, insecticides and herbicides.

Whilst industrialized countries have benefited from these advances in energy availability for agriculture, developing countries have not been so fortunate. "Energizing" the food production chain has been an essential feature of agricultural development throughout recent history and is a prime factor in helping to achieve food security. Developing countries have lagged behind industrialized countries in modernizing their energy inputs to agriculture.

As indicated in Chapter 1, agriculture accounts for only a relatively small proportion of total final energy demand in both industrialized and developing countries. In OECD countries, for example, around 3-5% of total final energy consumption is used directly in the agriculture sector. In developing countries, estimates are more difficult to find, but the equivalent figure is likely to be similar - a range of 4-8% of total final commercial energy use.

The data for energy use in agriculture also exclude the energy required for food processing and transport by agro-industries. Estimates of these activities range up to twice the energy reported solely in agriculture. Definitive data do not exist for many of these stages, and this is a particular problem in analysing developing country energy statistics. In addition, the data conceal how effective these energy inputs are in improving agricultural productivity. It is the relationships between the amounts and quality of the direct energy inputs to agriculture and the resulting productive output that are of most interest.

Agricultural Energy Needs

Agriculture practices in many developing countries continue to be based to a large extent on animal and human energy. Insufficient mechanical and electrical energy is available for agriculture, and hence the potential gains in agricultural productivity through the deployment of modern energy services are not being realized. Agricultural energy demand can be divided into direct and indirect energy needs. The direct energy needs include energy required for land preparation, cultivation, irrigation, harvesting, post-harvest processing, food production, storage and the transport of agricultural inputs and outputs. Indirect energy needs are in the form of sequestered energy in fertilizers, herbicides, pesticides, and insecticides.

Mankind has adapted a variety of resources to provide for energy in agriculture. Animal draught power obtained through domestication of cattle, horses and other animals has existed for over 8,000 years, the water wheel is over 2,000 years old, and windmills were introduced over 1,000 years ago. Direct sun energy for drying and biomass fuels for heating have also been prominent as agricultural energy inputs for centuries.

The bulk of direct energy inputs in developing countries, particularly in the subsistence agriculture sector, is in the form of human and animal work. **Human work has a limited output, but humans are versatile, dextrous and can make judgements as they work.** This gives humans an advantage in skilled operations such as transplanting, weeding, harvesting of fruits and vegetables and working with fibres. Water lifting and soil preparation need less skill but more energy input. A sustainable rate at

ISBN: **978-93-85822-54-4**

which a fit person can use up energy is around 250-300 W, depending on climate and needing 10-30 minutes/hour rest. The efficiency of energy conversion is only about 25%, with a maximum sustainable power output of 75 W. The following table lists human power consumption for various farming activities (Carruthers and Rodriquez, 1992).

Table: Human power consumption for various farming activities

Activity	**Gross power consumed (W)**
Clearing bush and scrub/felling trees	400-600
Hoeing, planting	200-500
Ridging, deep digging	400-1000
Ploughing with draught animal	350-550
Driving 4 wheel tractor	150-300
Driving single axle tractor	350-650

Energy and Agro processing

The agro processing industry transforms products originating from agriculture into both food and non-food commodities. Processes range from simple preservation (such as sun drying) and operations closely related to harvesting, to the production, by modern, capital-intensive methods of such articles as textiles, pulp and paper. Upstream industries are engaged in the initial processing of products, with examples such as rice and flour milling, leather tanning, cotton ginning, oil pressing, saw milling and fish canning. Downstream industries undertake further manufacturing operations on intermediate products made from agricultural materials. Examples are bread and noodle making, textile spinning and weaving, paper production, clothing and footwear manufacture and rubber manufacture.

An energy input is required in food processing, as well as in packaging, distribution and storage. Many food crops when harvested cannot be consumed directly, but must pass through several stages of processing as well as cooking in order to be palatable and digestible. Raw meats, uncooked grains, vegetables and even fruits require preparation and heating to enhance their flavour, rendering their components edible and digestible. The processing and cooking stages reduce harmful organisms and parasites, which might pose health hazards.

ISBN: **978-93-85822-54-4**

Poorly handled and stored food can become spoiled and contaminated. Food preservation usually requires the application of heat to destroy micro-biological agents, such as bacteria, yeast and mould. Pasteurization causes the inactivation of spoilage enzymes and reduction of bacteria at temperatures around 80-90^{o}C. Heat sterilization can use atmospheric steam at 100^{o}C for high-acid foods, and pressurized steam at around 120^{o}C for low acid foods. Other techniques include dehydration to reduce moisture content, pickling/smoking to reduce microbial activity, fermentation, salting and freezing.

Food transformation activities are generally less energy-intensive and release less CO_2 and metal residues than most other industrial activities per unit of product. As described in more detail below, agroprocessing industries, such as sugar mills, can become not only energy self-sufficient through the energy conversion of biomass residues, but also electricity producers for export to other users.

Use of Measurable Indicators

Ways of measuring the sustainability of energy and agriculture and in particular the benefits of improved energy services for agriculture need to be established, so that indicators of progress can be developed. For example, current work on sustainability indicators could be adapted to include energy and agriculture[16]. Such measures would assist the establishment of a bridge between the rural energy and agricultural policy dimensions so that agricultural energy needs can be included in overall energy planning and policy formation. FAO has initiated work in this field and is developing energy indicators of sustainable agriculture. A third linkage is between the environmental dimension and energy use by agriculture, and suitable indicators of this also need to be developed.

Energy problems and solutions for agriculture should always be guided by local economic, environmental and social considerations. Energy policy formation should bring together national energy development policies with the locally perceived priorities. There needs to be increased emphasis on non-fossil fuel alternatives to the provision of energy services in agriculture in developing countries (Best, 1997). These range from the modern renewable energy sources, such as improved biomass conversion (including liquid biofuels, biogas, gasification), solar energy (PV), wind and

ISBN: **978-93-85822-54-4**

geothermal energy and small-scale hydropower, to lower energy intensity industries, material and energy recycling and better means of utilizing traditional energy sources, such as improved cooking stoves. In addition, there needs to be improved energy efficiency in mechanical equipment and in drying and separating operations.

The agriculture sector can move towards a path of greater sustainability through the application of improved techniques and practices such as conservation agriculture, organic farming, protecting agro-biodiversity, better water and soil management, and integrated pest management and plant nutrition. Where appropriate a greater level of mechanization and improved food-processing technologies are also important. The main challenge in the medium term for energy in agriculture is to mobilize the changes occurring in both the energy supply and the agricultural sectors to the benefit of rural livelihoods and communities. There is a danger that rural populations could be left behind unless energy policies are directed specifically on their needs. It seems clear from the analysis presented in this Chapter that energy requirements should be appropriately considered and integrated into agricultural and rural development programmes.

General objective:-

- To study social ecology and energy consumption pattern in farm metabolism.

Specific Objectives:-

i. To conceptualize the analytical form of farm metabolism.

ii. To isolate the variables (causal and consequent) which are in interactive relationship to characterize the farm metabolism.

iii. To elucidated and estimate the operational interaction through coefficient of correlation and regression as well as strategic interaction through path analysis,

iv. canonical covariates and canonical discriminant amongst and between the causal and consequent variables i.e. X_1………….X_{19} and Y_1…………Y_6.

ISBN: **978-93-85822-54-4**

v. To generate a micro level policy on farm energy metabolism that can be replicated in both the similar and exotic situation.

ISBN: **978-93-85822-54-4**